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NORTH CAROLINA GEOLOGICAL AND  
ECONOMIC SURVEY

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BULLETIN NO. 12

HISTORY OF THE GEMS FOUND IN  
NORTH CAROLINA

REDACTED BY THE STATE OF NC



BY J. M. HARRIS, JR.  
OF THE GEOLOGICAL SURVEY OF NORTH CAROLINA  
1910



**HISTORY OF THE GEMS FOUND IN  
NORTH CAROLINA**

**BY  
GEORGE FREDERICK KUNZ, Ph.D.**



**NORTH CAROLINA GEOLOGICAL AND  
ECONOMIC SURVEY**

**JOSEPH HYDE PRATT, STATE GEOLOGIST**

---

**BULLETIN NO. 12**

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**BY  
GEORGE FREDERICK KUNZ, PH.D.**



**RALEIGH  
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1907**



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## LETTER OF TRANSMITTAL

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CHAPEL HILL, N. C., November 15, 1906.

*To His Excellency, HON. R. B. GLENN,*

*Governor of North Carolina.*

**Sir.**—I have the honor to submit for publication as Bulletin No. 12 of the Geological and Economic Survey, the report of Dr. George Frederick Kunz on the History of the Gems found in North Carolina.

Yours obediently,

JOSEPH HYDE PRATT,  
*State Geologist.*



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## PREFACE

The preparation of the report on the History of the Gems Found in North Carolina was turned over to Dr. George Frederick Kunz of New York as the recognized authority on gems. He has had access to all the information relating to gems and gem minerals on file in the office of the Survey, and has also drawn freely from the various publications by himself and others relating to the gems of the State. In his introduction, Dr. Kunz calls attention to the fact that the production of gems in the State has been largely incidental to the mining and production of some other mineral and that there have been but few localities that have been developed solely for gems. At the present time, however, there are several companies operating in North Carolina simply for gem minerals, the two more important companies being the United States Ruby Company and the American Gem and Pearl Company.

The report is freely illustrated and many of the colored illustrations are of gems in the Morgan-Tiffany and Morgan-Bement collections at the American Museum of Natural History of New York City.

Chapter I gives a brief historical sketch of gem mining in the State, but detailed accounts are given in many instances under the head of the individual mineral.

The various gem minerals are described in the next five chapters. The localities are also given and reference is made to the commercial value of the gem material found.

This report does not pretend to take up a detailed account of the geological occurrences of the gem minerals, or a study of their chemical and physical characteristics, as these will be discussed in a later publication. It has been published especially for distribution at the Jamestown Exposition.

JOSEPH HYDE PRATT,  
*State Geologist.*

total product has been very considerable; but, strange as it may seem, many of the discarded gold-washings of a century ago are now yielding more to the owner of the land for the obscure and long unknown monazite sands than for the gold originally obtained with them. In regard to this latest development, extended mining has recently shown that the hillsides, from which the monazite sands in the "branches" and streams originally came, contain an endless store of these rare minerals, and that when the ancient brook-washings are exhausted, the hillsides can be resorted to for a century to come. It is in the search for this mineral that most of the small and beautiful garnets, rutiles, sapphires, epidotes, and other gems have lately been found.

Between the gold-mining of earlier times and the more recent and varied developments, came the terrible years of the "war between the States." When that was past, brave and patriotic men like the late Gen. Thomas L. Clingman, afterwards United States Senator, turned their attention to developing the natural resources of their State and retrieving in every way possible the ruin and devastation that had swept over the South. Then commenced a period of exploration and discovery in the mineral and gem treasures of North Carolina that has progressed and expanded to a wonderful extent. It began with the corundum industry and the mica mines. The presence of the former mineral had been known for some years before the war, but it had not been developed. The first notice of its occurrence in the State was in 1846, by Prof. C. D. Smith, but with no particulars as to the locality. About 1850 General Clingman announced it from Madison County; and in 1852, Prof. R. T. Brumby, of the College of South Carolina, collected and labelled specimens from Clubb Mountain, in Lincoln County, and placed them in the College cabinet at Columbia, S. C. In the next year Professor Ebenezer Emmons, of the University of North Carolina, in a report on the midland counties of the State, mentioned a discovery of corundum by Dr. C. L. Hunter, in Gaston County. Little or nothing was done in regard to it, however, until immediately after the war, in 1865, when the Rev. C. D. Smith, of Franklin, Macon County, who had been an assistant to Prof. Ebenezer Emmons on the Geological Survey of the State, identified specimens that were brought to him, visited the spot whence they came, and discovered a number of important localities. In the next 5 years a great amount of exploration was done, mines were opened, and an important and enduring industry was called into being. Among those most active in this field of study and progress, besides Mr. Smith and General Clingman, were the able State Geologist, Prof. Washington C. Kerr, the enthusiastic and indefatigable collector, Mr. J. Adlai D. Stephenson, of Statesville, and

Mr. C. W. Jenks, who opened the Corundum Hill mine, at Franklin, N. C., about 1870, and was the first to find gem sapphire in its original matrix. During the same period, numerous valuable scientific reports and analyses were prepared and published by such authorities as Prof. F. A. Genth, Dr. J. Lawrence Smith, and Dr. T. M. Chatard; and the North Carolina corundum, its history, mineralogy, and composition, was thus made widely known.

Although the main value of the mineral as mined was for use as an abrasive material, yet pieces were obtained that had color and transparency enough to rank them in some cases as true gems and largely as valuable specimens. Among the first fine crystals were some obtained by Prof. C. U. Shepard; one of these, now in the Shepard collection at Amherst College, Mass., weighs over 300 pounds. Besides the collecting tours of Professor Shepard, many annual visits were made to the corundum region by Mr. Norman Spang, of Pittsburg, Pa., a wealthy and noted collector, who encouraged exploration, and brought back with him much of the choicest of the "treasure trove." Mr. W. E. Hidden, of New York, devoted a large part of 20 years to energetic and intelligent search for minerals and gems with wonderful success; and recently the State Geologist, Dr. Joseph H. Pratt, and Prof. J. V. Lewis have given extended and detailed study to the whole subject of the various occurrences of corundum in the State. All this activity has not only developed the industry itself, but has led incidentally to other discoveries. It may be, indeed, that more has been spent in the search and in attempts at mining, not always judicious, than the product itself has yielded; but the effect on the development of the State has been immense. In the matter of gems and remarkable specimens, these years of exploration have successively brought to light one and another fine gem, crystal, or rare mineral, to such an extent that to-day, were the North Carolina specimens removed from the great collections of the world, a gap would be left that could not be filled, in such places as the American Museum of Natural History, New York, the British Museum of London, the Imperial Museum of Vienna, the U. S. National Museum at Washington, the Field Columbian Museum of Chicago, the Musée de Histoire Naturelle, Paris; and many others, important but less famous.

During the same general period, the mining of mica came to be another important industry in the revival of the State, and this also led to discoveries of other rare minerals in the search for valuable localities for mica. One of the most curious and interesting facts brought to light in this connection, was the clear evidence that some of the best mica mines had been long and extensively worked by ancient aborigines, either Indians



or earlier "mound-builders" (if these indeed be distinct peoples), or both. Ornaments cut from mica, as also shells and quartz crystals, are not uncommon in the burial-mounds of the Mississippi valley; and, as no mica occurs in that part of the country, it is clear that the old excavations, rudely made with stone tools, along the outcrops of large mica veins in North Carolina, were the source of this material, which was evidently prized by the prehistoric tribes and widely distributed among them.

It is a "far cry" from prehistoric mounds and ancient and long-forgotten mica mines to the incandescent lighting of our present civilization and the properties of rare chemical elements. But such are some of the contrasts that present themselves in speaking of North Carolina minerals. It is now some 18 years since the introduction of the Welsbach incandescent burner, or rather mantle, that has so improved our gas illumination. Instead of using the light produced by white hot carbon particles, as in ordinary flame, a hood or mantle is employed, which, when heated by the burning gas, glows with far greater intensity. This mantle consists of a loosely woven fabric impregnated with certain compounds of rare elements. The first forms of it employed zirconia salts; and this fact led to active mining of the small, opaque, and previously unimportant zircon crystals that are abundant at several points in North Carolina. Since then it has been found that even greater brilliancy is obtained by the use of nitrate of thorium. This latter is a rare metal, found in very few minerals and in small amounts; but it is notably present in monazite, a phosphate of this and other oxides of rare elements. Monazite was formerly regarded as a very uncommon mineral, but it has been found to occur quite abundantly in the sands of the stream-beds in the South Mountain region, comprising several counties of North Carolina, being derived from the disintegration of the country rock. Thus the monazite industry has now become highly important, and it is likely to continue and increase; as the demand for thorium salts for incandescent burners is very great. This latest stage of North Carolina mining—the search for the "rare earths," so-called—has developed extensively within a few years; though General Clingman was active in the earlier stages of it, in promoting the zircon mining, and Mr. W. E. Hidden first brought into use the monazite sands, and induced the Welsbach Company to experiment with them in 1884. In 1901 the monazite output of North Carolina was 748,000 pounds, valued at some \$50,000. Only Brazil surpasses, or even approaches, this production. In 1906 the output was 697,275 pounds, valued at \$125,510. A total of 8,426,004 pounds valued at \$635,568, was mined in the 14 years 1893 to 1906, inclusive.

With these general historical outlines in mind, we may pass to a more

special account of North Carolina gems, that have been found, as above noted, chiefly as incidents in the course of mining enterprises.

The diamonds of North Carolina, although small in size and few in number, are undoubtedly authentic. The localities have been visited and the discoveries verified by good mineralogists. Whether their occurrence will always be as sporadic as these, or whether others will be found, time only can tell. Rubies, as fine in color as those of Burma, but generally small or containing imperfections, have lately been found in the Cowee Valley, in Macon County; considerable mining for them has been done, but the financial outcome is still somewhat problematical. Emeralds, remarkable as crystals, but rarely transparent enough for gems, were obtained in Alexander County, some years ago; but a greater quantity has been sold from the more recent Crabtree Mountain discovery, in Mitchell County, where the emerald is translucent to transparent, in a white granitic rock, and the whole is cut together as a matrix material—the quartz and feldspar contrasting charmingly with the emerald green. Aquamarines, which for beauty of colors have never been rivalled in any country of the world, have been found in some profusion, and many gems have been cut weighing from 1 to 30 carats, of the most beautiful sea-blue color. Beryls, both sea-green and yellow, than which none richer have ever been found, are also obtained in Mitchell County and elsewhere. Mention should also be made of the peculiar “lithia emerald,” or hiddenite, found with the large emerald crystals above noted, at Stony Point, Alexander County. This gem-stone was discovered in 1879 by J. Adlai D. Stephenson, then sent by William E. Hidden to Dr. J. Lawrence Smith of Louisville, who named it *hiddenite*. The garnets of the gold washings are well known; but it remained for the Cowee Valley to produce a new variety of garnet which has received a distinct name, *rhodolite*, and has brought of late greater financial returns, probably, than any other North Carolina gem. The amethysts from various localities equal those found in any country of the globe; while smoky quartz, wonderful as crystals, that have commanded the attention and study of some of the greatest living crystallographers, has been obtained in Alexander and adjoining counties. These specimens have frequently been fine enough to cut into gems. But quartz in its choicest form,—rock crystal—has been found in Ashe County in such magnificent masses that one of the finest art objects shown at the Paris Exposition of 1900, was made from rock crystal obtained in this county in 1888 by the author as was the cover of the “Adams gold vase” presented to the same museum. These now form parts of the Matthiessen gift and Edward D. Adams gift to the Metropolitan Museum of Art, in New York, where they are two of the finest objects in the entire museum.

or earlier "mound-builders" (if these indeed be distinct peoples), or both. Ornaments cut from mica, as also shells and quartz crystals, are not uncommon in the burial-mounds of the Mississippi valley; and, as no mica occurs in that part of the country, it is clear that the old excavations, rudely made with stone tools, along the outcrops of large mica veins in North Carolina, were the source of this material, which was evidently prized by the prehistoric tribes and widely distributed among them.

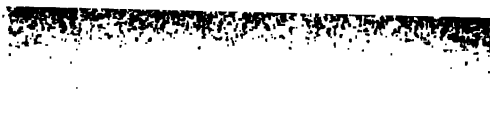
It is a "far cry" from prehistoric mounds and ancient and long-forgotten mica mines to the incandescent lighting of our present civilization and the properties of rare chemical elements. But such are some of the contrasts that present themselves in speaking of North Carolina minerals. It is now some 18 years since the introduction of the Welsbach incandescent burner, or rather mantle, that has so improved our gas illumination. Instead of using the light produced by white hot carbon particles, as in ordinary flame, a hood or mantle is employed, which, when heated by the burning gas, glows with far greater intensity. This mantle consists of a loosely woven fabric impregnated with certain compounds of rare elements. The first forms of it employed zirconia salts; and this fact led to active mining of the small, opaque, and previously unimportant zircon crystals that are abundant at several points in North Carolina. Since then it has been found that even greater brilliancy is obtained by the use of nitrate of thorium. This latter is a rare metal, found in very few minerals and in small amounts; but it is notably present in monazite, a phosphate of this and other oxides of rare elements. Monazite was formerly regarded as a very uncommon mineral, but it has been found to occur quite abundantly in the sands of the stream-beds in the South Mountain region, comprising several counties of North Carolina, being derived from the disintegration of the country rock. Thus the monazite industry has now become highly important, and it is likely to continue and increase; as the demand for thorium salts for incandescent burners is very great. This latest stage of North Carolina mining—the search for the "rare earths," so-called—has developed extensively within a few years; though General Clingman was active in the earlier stages of it, in promoting the zircon mining, and Mr. W. E. Hidden first brought into use the monazite sands, and induced the Welsbach Company to experiment with them in 1884. In 1901 the monazite output of North Carolina was 748,000 pounds, valued at some \$50,000. Only Brazil surpasses, or even approaches, this production. In 1906 the output was 697,275 pounds, valued at \$125,510. A total of 8,426,004 pounds valued at \$635,568, was mined in the 14 years 1893 to 1906, inclusive.

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The mineral collections in the State Museum at Raleigh include a number of valuable and interesting collections of gems and gem minerals prominent among which is that of Mr. J. A. D. Stephenson, for more than 30 years a resident of North Carolina and an enthusiastic explorer of its natural resources.

Much credit is also due to the late James D. Yerrington, for many years the agent of the Henry D. Morse Diamond-Cutting Company, who for 30 years carried on correspondence with North Carolina, doing much by his kindly advice and care to encourage the people to send small gems, which in many cases led to valuable results.

GEORGE FREDERICK KUNZ.













A

Section of a sapphire crystal,  
banded blue and yellow, Jenkins Mine, Marion County,  
North Carolina.



B

Asteriated sapphire,  
Jackson County,  
North Carolina



C

Ruby,  
Jenkins Mine, Marion County,  
North Carolina



D

First sapphire found in matrix at  
Cottonwood Hill, Marion County,  
North Carolina.  
Restored to matrix after being cut



E

Sapphire (Brown),  
Cherokee  
McDowell County,  
North Carolina



F

Ruby,  
Cotton Valley,

Marion County, North Carolina



G

Ruby,  
Cotton Valley,  
Marion County, North Carolina

# HISTORY OF THE GEMS FOUND IN NORTH CAROLINA

By GEORGE F. HODGES, 1882-1910.

## CHAPTER I

### HISTORICAL VALUE OF THE GEM MINES.

Gem mining in North Carolina has been a constant industry, and is called crystal mining. It has been carried on by the Indians, and by the white people, as early as the first settlement. The first white settler, John Ogdon, then located in the western part of the State, near the present town of Lenoir, was the first to mine for crystals. He was a Scotchman, and his garnet crystals of watchful quality were highly valued. The crystals were flattened between the hands of the miner.

The first systematic mining of crystals was carried on by Mr. John Jones, in 1811, when he began to mine for crystals in the western part of Franklin, Marion, and Wayne counties. He was the first to mine for many rhombic gems, and also for the garnets of the Deersfoot series. The mine became so rich that he was able to produce a large quantity of rhombic gems for exportation. The mine was worked for many years, and the crystals were of high quality. The mine was worked for many years, and the crystals were of high quality. The mine was worked for many years, and the crystals were of high quality.

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# HISTORY OF THE GEMS FOUND IN NORTH CAROLINA.

By GEORGE FREDERICK KUNZ, PH. D.

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## CHAPTER I.

### HISTORICAL SKETCH OF GEM MINING.

Gem mining in North Carolina had its origin; first, in the finding of rolled crystals in the gold washings in several counties, some of them of gem value, notably a few diamonds and occasionally a zircon or epidote; then in the development of the mica mines, some of which furnished some very beautiful beryls and others, garnets. Some of the garnet crystals of wonderful color and brilliancy were frequently found flattened between the plates of mica.

The first systematic mining for gems was undertaken by Mr. C. W. Jenks, in 1871, when he opened the corundum mine, on Corundum Hill, near Franklin, Macon County. This proved interesting scientifically, and many choice gems were obtained; and the name of the Jenks, or Culsagee, mine became noted. The amount of gems found, however, did not warrant permanent operations for gem corundum only, and after a few years the mine was operated for corundum for abrasive purposes. Another promising mine, opened soon afterwards, was the Buck Creek, or Cullakeenee mine, in Clay County; but this has had much the same history. Next came the mining for emeralds in Alexander County, at Stony Point, where crystals had been found loose in the soil formed by the disintegration of the country rock. As this region has never been subjected to glacial action, as the northern part of the country has, anything found in the soil, apart from stream-beds, has its origin presumably near the spot where it is met with. The entire soil and upper portions of the rocks here consist of what Professor Kerr called the "frost drift," *i. e.*, the same as the underlying rock, but decayed and decomposed by frost and weathering in general. Credit should be given here to the late Mr. J. Adlai D. Stephenson, of Statesville, who recognized these conditions and stimulated the country people to search the surface of their fields for such crystals, of

which he gathered a great collection, in the hope of locating mines near the points where anything of special interest was encountered. It was thus that the emerald locality at Stony Point, which also yielded the new and remarkable hiddenite gems, was traced. Later, the beryl mine at Spruce Pine, Mitchell County (Pl. II), was opened, and worked from time to time, affording beautiful beryls. Then came the discovery of true rubies near Franklin, Macon County, which has led to considerable development and to the finding of some crystals which had gem value, although never very great. Near this place occurs also the rhodolite—a garnet between pyrope and almandite. This has been developed by two companies with remarkable success, and apparently more gems in value have been sold from this mine than from all other sources in North Carolina combined. More recent still is the development of the emerald matrix mine at Crabtree Mountain, near Bakersville, in Mitchell County. Here the emerald occurs as small richly colored crystals, thickly strewn through a white matrix of feldspar and quartz; and the whole rock is cut and polished together, as a green and white ornamental stone, which is quite in favor. Amethyst of good quality, but not to any great extent, has been developed in Lincoln and Macon counties.

Thus far, with the exception of rhodolite and beryl, the gem mines of North Carolina have not proved remunerative enough to warrant a continued development, either from absence of sufficiently rich material or else from the use of methods that lacked cohesiveness to assure success.

A few notes may be given here as to some of the circumstances connected with mining development and the men who were active in it. General Clingman has been referred to already; another early and very active worker was Mr. C. W. Jenks, who will be mentioned further in relation to the first corundum development. One of the most energetic explorers and discoverers of North Carolina minerals was Mr. J. A. D. Stephenson, of Statesville. In 1888 he prepared for the author a summary of the results which he had attained in the years following the Civil War; and from this little unpublished work the following passages are taken, to show the spirit and the methods of his activity:

The Piedmont region lying between the Catawba and Yadkin rivers, is remarkable for the number of minerals, both common and rare, that are found in unusually fine crystals. Being a native of this section, and an ardent admirer of all the phenomena and beauties of nature, these crystals attracted my attention in early life, and the collection and study of them . . . convinced me that they were of more than usual interest; and my early experience in the placer gold mines of North Carolina familiarized me with the occurrence of such rare materials as monazite, xenotime, zircon, columbite, etc., in this region; and knowing that these materials are found



WISEMAN BERYL MINE, MITCHELL COUNTY, N. C., 18 MILES FROM MARION.



associated with precious stones in other countries, impressed me with the idea that by . . . systematic search, valuable gems would be found here, but want of time and opportunity delayed the search until 1874.

I selected this section as the most convenient for my work. But the same indications cross the State from northeast to southeast. In fact, to draw a line . . . from Paris, Maine, to Gainesville, Ga., it is surprising to me how near it passes all the gem localities east of the Mississippi River.

My plan . . . was to go among the people of the country, and endeavor to interest them in collecting the different crystals found in their respective sections; this I found an easy matter, especially with the children, as they took hold of the idea readily and many of them soon became familiar with the work, and not only did good service in developing the mineral resources of the State, but many of them have acquired a good knowledge of mineralogy and general natural history.

Mr. Stephenson's discoveries form almost the only exception to the general statement made at the outset, that the discoveries of gems and gem-minerals in North Carolina arose incidentally in the search or mining for gold, corundum, mica, or the rare earths. Mr. Stephenson had described how he set about the search for gems directly, in the assurance that they must exist and could be traced by sufficient endeavor. In almost all other cases, the discoveries have been made accidentally in the course of other mining operations.

A recent letter to the writer from Mr. D. A. Bowman, of Bakersville, for example, states the usual facts as follows:

As to the discovery of beryl, and other gems, this was invariably by mica mining, for outside of a mica vein, I have never known a beryl to be found. In working for black mica, the beautiful beryl at Buchanan Mine was found. It was the same at Grassy Creek, where Wiseman and McKinney found the deep green aquamarines, and then sold to the "American Gem Company."

I identified the beryl found by Wiseman and McKinney and shipped it to Tiffany & Company.

It was Mr. Rorison and myself that first discovered the emerald matrix at Brush Creek Mountain, in 1894 or 1895. . . . For 35 years I have worked hard to bring to light the various minerals and gems, and through your kind assistance I feel I have not worked in vain, and have been of some little service to my country.

In the same letter, Mr. Bowman gives an interesting account of the first opening of a mica mine, shortly before the war. In 1858, General Clingman, while traveling in the western part of the State, stopped over night with a Mr. Silver, near Bakersville, and was interested to find a window filled with 8 by 10 inch panes cut from sheets of mica, or as it was generally called, isinglass. The very next day, having been shown the spot where this novel material was found, General Clingman hired workmen and began sinking a shaft. Mica was taken out in magnificent



## HISTORY OF THE GEMS FOUND IN NORTH CAROLINA.

blocks; but General Clingman was more interested in a brilliant pyrites in the adjacent feldspar, under the impression that it was a silver ore. After the war had closed, in 1869, the old mine, long known in the vicinity as the "Sink-hole," was brought to the notice of a stove company in Knoxville, Tenn., who began to operate it for the mica, with great success. Another mica mine in the same section, the "Cloudland," was discovered accidentally at about the same time, and proved to be also valuable. Quite a local excitement sprang up, and much prospecting was done for mica, with the result that several important mines were discovered. One of these, the "Clarissa," has yielded as much as half a million of dollars, by Mr. Bowman's estimate. It has been worked down to 400 feet, and is now stopped by water; but only awaits improved machinery and a rise in the price of mica, to be reopened with profit. With all that has been discovered, however, and all that has been done,

in North Carolina gems, there are evidently much greater possibilities in the future. One suggestion of a practical kind may be made in closing this introductory chapter.

A wonderful development has gone on in North Carolina in the direction of the great hotels at Asheville and Toxaway and the mountain resorts at Linville, Cranberry and elsewhere, and a large tourist class visit this region every year. If some of the native prospectors should use their spare moments as do those in Russia, they would gather, mine and then cut the rock crystals, smoky quartz, and other stones of the region shaping them into ornamental forms, as the inhabitants of the Ure Mountains have done since the eighteenth century, when Catherine the Second sent two Italian lapidaries to educate them in the art. This might well prove a source of interest and profit to the people of the State.

## CHAPTER II.

### DIAMOND

The mining of gems in this State had its origin in the finding of rolled crystals of gem value in the gold washings. In these regions have been found crystals of diamond, either loose in the soil, or taken from the washings of auriferous gravel.<sup>1</sup> The portion of the State which has yielded these valuable substances is that known as the Piedmont region—a broad belt of country, as its name indicates, at the foot of the mountains, along the eastern base of the Blue Ridge. The rocks here are metamorphic and crystalline, with some Cambrian beds a little farther west. There runs throughout much of this region a belt or belts of itacolumite, the so-called “flexible sandstone,” which is also found in Brazil and in the Ural Mountains, and has frequently been supposed to be the matrix of diamond crystals. The presence of this peculiar rock and the occasional discovery of diamonds in adjacent districts have led to the idea that the itacolumite belt of North Carolina might prove to be a valuable diamantiferous region; but as yet no diamonds have actually been discovered there, and but few have been found in the loose débris of the crystalline beds. The late Prof. Frederick A. Genth, of the University of Pennsylvania, described<sup>2</sup> the occurrence of the 2 crystalline varieties of carbon in that State,—the graphite in beds interstratified with schist or gneiss; the diamond in the débris of such rocks, associated with gold, zircon, garnet, monazite, and other minerals, and after speaking of this occurrence in connection with rocks of identical age, as a very interesting circumstance, he says: “The diamond has not been observed in North Carolina in any more recent strata, and in the itacolumite regions no diamonds have ever been found, as in Brazil; from which it appears that the itacolumite of Brazil is either simply a quartzose mica slate of similar age with the North Carolina gneissoid rocks, or, if it be contemporary with the North Carolina itacolumite, the diamonds were not produced in the same, but came from the older rocks and were redeposited with the sands resulting from the reduction to powder of these, and are now found imbedded in the same, their hardness having prevented their destruction. Seven or 8 diamonds have thus been found. They occur distributed

<sup>1</sup> *Gems and Gem Mining in the South*, by Joseph Hyde Pratt; *The Southland*, Vol. I, No. 2, p. 4, 1901.

<sup>2</sup> *Mineral Resources of North Carolina*, p. 28, Philadelphia, 1871.

over a wide area of surface in the counties of Burke, Rutherford, Lincoln, Mecklenburg, and Franklin, and I have no doubt if a regular search were to be made for them, they would be more frequently found." To the counties named by Professor Genth, must now be added McDowell, and these all form, with the exception of Franklin, a group lying together in the line of the general drainage of the country, southeast of the Blue Ridge. Franklin County is far to the northeast of the others; and any diamonds occurring there must be derived from the disintegration of another belt of crystalline rocks, that traverses the eastern portion of the State, near Weldon, in Halifax County, or else have been transported for a long distance by streams.

Up to the present time there are about ten authentic occurrences of diamonds in North Carolina, besides several reported discoveries that are not entirely reliable.\* One such instance was that of a quartz crystal found near Danbury, which was examined, and pronounced a (genuine) diamond, by the local jewelers, who valued it erroneously at some thousands of dollars.

The first specimen in order of time, was found in 1843, by Dr. F. M. Stephenson, at the ford of Brindletown Creek, in Burke County. It was an octahedral crystal, and was valued at \$100; but no particulars of it are on record. Another was found in the same neighborhood by Prof. George W. Featherstonhaugh, but there seems to be no account of its characters preserved. In 1845, a diamond of  $1\frac{1}{2}$  carats, a distorted octahedron with curved faces, clear and flawless, though tinged with yellow, was found in the gold washings of J. D. Twitty's mine, in Rutherford County. It became the property of the late General T. L. Clingman, of Asheville, who for many years took great interest and did great service in developing the mineral resources of North Carolina. This stone was described by Prof. Charles U. Shepard,<sup>4</sup> who announced the existence of itacolumite in the gold-bearing region of North Carolina, at the meeting of the American Association of Geologists and Naturalists in 1845, and under the impression that the itacolumite is their matrix, had predicted the further discovery of diamonds in that region, as in Brazil. For this reason diamonds, when found, were naturally submitted to him. C. Leventhorpe, of Patterson, Caldwell County, N. C., reports a small and poor specimen found in a placer mine on his property in Rutherford County, and states that he presented it to Prof. Shepard, who retained it in his cabinet. The next important diamond was found in gold-washings

\* Sketch of N. C., issued by the Dept. of Agriculture, Raleigh, to accompany the State Exhibit at the Charleston Exposition, 1902. Diamond, pp. 40, 41.

<sup>4</sup> Am. Jour. Sci., Vol. II, p. 253, Sept., 1846.

in 1852, by Dr. C. L. Hunter, near Cottage Home, Lincoln County. It is described as an elongated octahedron of a delicate greenish tint, transparent, and about half a carat in weight. Another, said to be a very handsome white crystal of 1 carat, was obtained in the same year, at Todd's Branch, Mecklenburg County; it became the property of the late Dr. Andrews, of Charlotte, N. C., who also informed Prof. Genth that a beautiful black stone "as large as a chinquapin" was afterwards found by some gold-washers in the same locality. This specimen, unfortunately, was crushed with a hammer, sharing the fate of several American diamonds when submitted to the mistaken test which confounds hardness with strength. The fragments of the black diamond scratched corundum with ease, thereby proving its genuineness.\* Soon after this two diamonds, one a beautiful octahedron, were reported by Prof. F. A. Genth, as obtained at the Portis mine, in Franklin County. This locality is far removed from the others in North Carolina,—a point which is referred to presently.

Two discoveries are recorded in McDowell County, one of two or three small crystals found at the headwaters of Muddy Creek, and the other a fine stone picked up at a spring near Dysartville, in 1886.\* This was a distorted and twinned hexoctahedron, of  $4\frac{1}{2}$  carats, transparent, with a grayish-green tint. The little son of Mr. Grayson Christie, going for water to a spring on the farm of Alfred Bright, observed this peculiar shining pebble, and brought it home. After some local interest had developed, its nature was suspected, and it was sent to New York and there at once identified. A model of it was exhibited at the Paris Exposition of 1889, and is now in the Tiffany-Morgan collection of the American Museum of Natural History. The present writer subsequently visited the spot, and fully authenticated all the facts of the discovery. The sediment in the bed of the spring was taken out and examined, and also the small hollows on the adjacent hillside. None of the ordinary associations of the diamond were observed, and hence it is probable that the crystal was washed down with decomposing rock-soil from higher ground, perhaps during some freshet; or possibly it may have been carried to the spring by miners, and left unobserved or unrecognized among the "wash-up" of the gold-bearing sand from some neighboring placer. There are gold mines in McDowell County, worked chiefly by hydraulic sluicing, but as a rule the stones that remain in the sluices are carefully examined, as the miners know that gems are sometimes thus found. The value of the Dysartville diamond as a jewel will hardly represent the

\* *Handbook of North Carolina*, Raleigh, 1886, pp. 197, 198.

\* *Am. Jour. Sci.*, Vol. XXXIV, Dec., 1887, p. 490.

interest that attaches to it as a local specimen of large size and fine appearance. (See Plate III.)

Another diamond is reported to have been found 9 years before, in 1877, by a small boy, in the same region as the last. It weighed  $2\frac{3}{8}$  carats, and is described as white and lustrous, but somewhat flawed, and of irregular flattened form, resembling a bean, with the crystal faces obscure. The finder sold it in Marion for a mere nominal sum. Mr. B. B. Price, of Marion, put it for disposal into the hands of Mr. James M. Gere, of Spruce Pine, an extensive buyer and miner of North Carolina mica. He took it to Syracuse, N. Y., and sold it there to Messrs. C. M. Ball & Co., jewelers, for the sum of \$18. It was finally sent to New York, where it was cut into a small gem and its identity lost.<sup>7</sup>

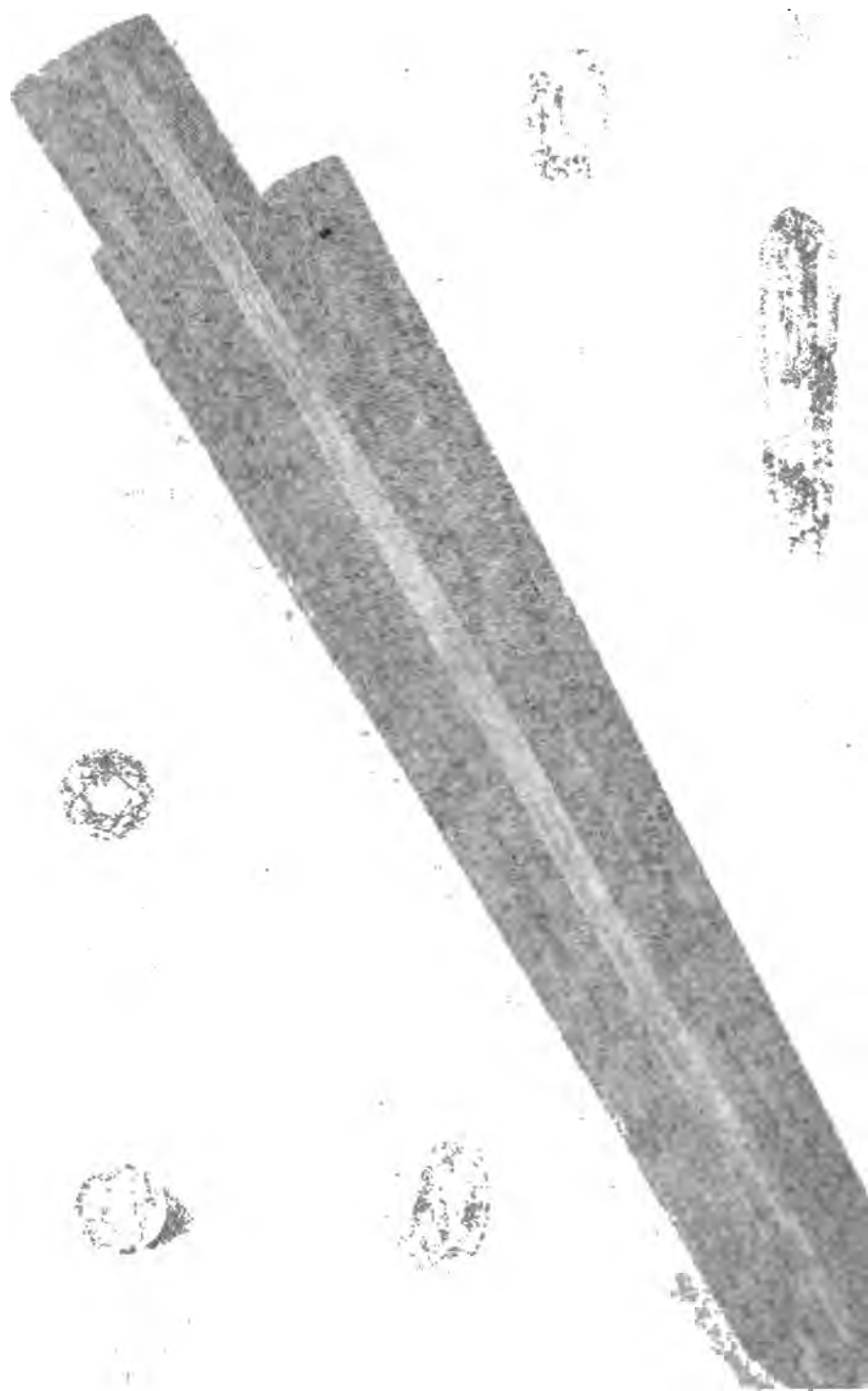
Still another crystal is in the State Museum at Raleigh. The particulars of its discovery are not known; but it was purchased by the State with the collection of the late Dr. J. A. D. Stephenson, of Statesville, N. C., who had possessed it for some years, and reported that he had bought it, with other minerals, from a countryman in Burke County. It has an oblong spheroidal form, the faces being curved and rounded; and it weighs  $\frac{5}{16}$  of a carat. These particulars are given in a recent letter from Mr. T. K. Brunner, Secretary of the State Department of Agriculture at Raleigh.

The latest well established discovery was in 1893, in Cleveland County, near King's Mountain. It was a polished octahedron, weighing  $\frac{3}{4}$  carat, of a bright light canary yellow.

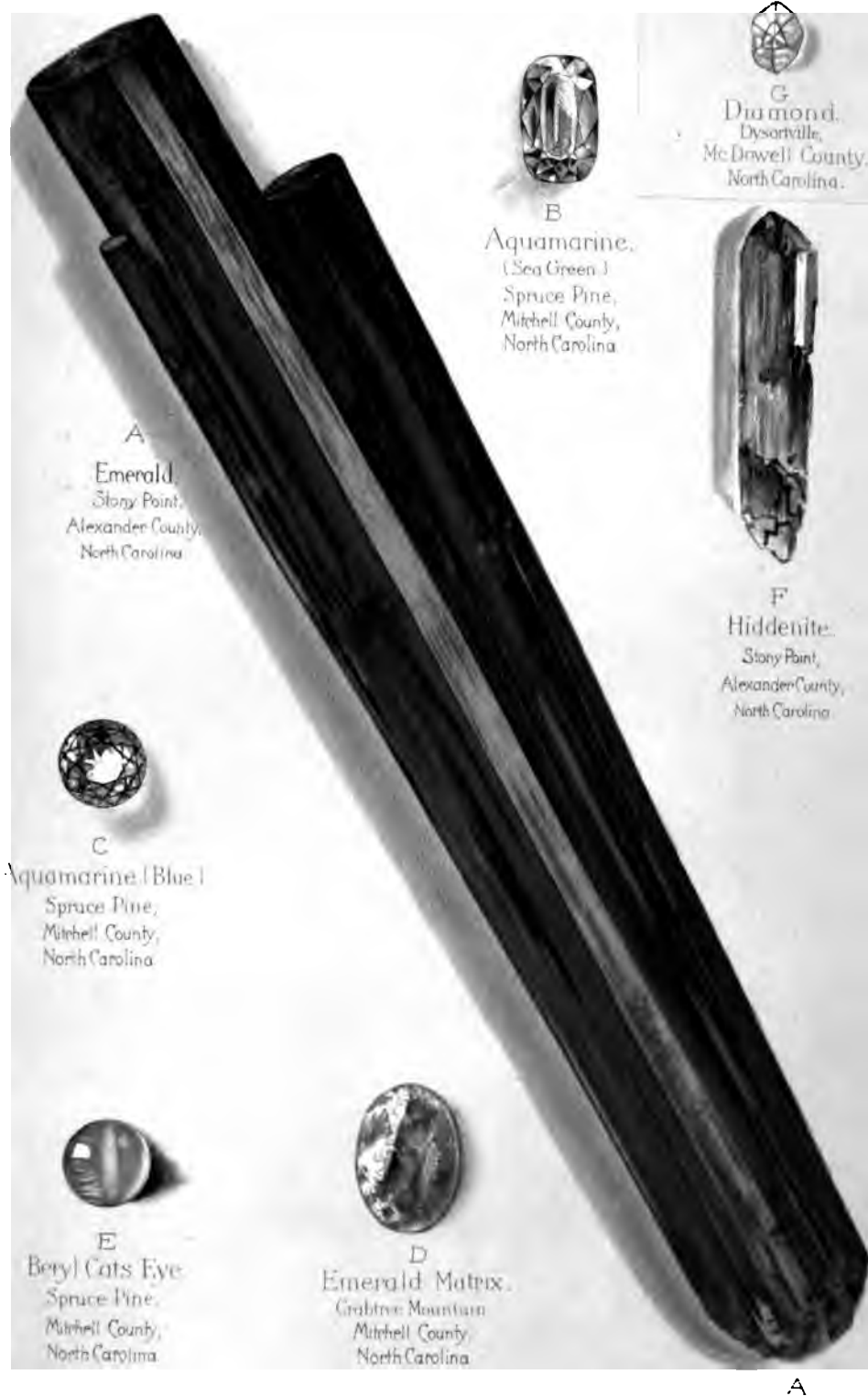
It will be noticed that most of these localities are situated in the same section of the State,—in the mountainous district, lying just north from the northernmost extension of the border of South Carolina. Here the counties of Burke, Rutherford, McDowell, and Cleveland lie closely adjacent, and Mecklenburg only a short distance eastward.

The foregoing list includes all the authentic diamonds thus far discovered in North Carolina. A number of small stones, exhibited as diamonds, have been found at Brackettstown. They are similar to supposed diamonds found by J. C. Mills at his mine at Brindletown, but these were transparent zircon or smoky-colored quartz, the former of which has a lustre readily mistaken by an inexperienced person for that of a diamond. A number of pieces of rough diamond, exhibited as from the same section, have been decided to be of South African, not Carolinian origin. It is to be hoped that the few legitimate discoveries

<sup>7</sup> Addendum to the "Minerals and Mineral Localities of North Carolina," by William Earl Hidden, p. 2, 1889; Reprinted from Jour. of the Elisha Mitchell Scientific Society, 6th year, part II. Raleigh, 1890.











actually made in this locality will not lead to deceptions, which would greatly retard any natural development of interest. It is quite possible that diamonds may be found widely distributed throughout the auriferous belt of the Carolinas and northern Georgia; and that, in the often rude and hurried methods of gold-washing employed, they may have been overlooked in the past, and now lie buried in the piles of sand that stretch for miles along the water-courses.\* It is stated that 3 diamond crystals were obtained many years ago on Koko Creek, at the headwaters of the Tellico River, in East Tennessee, on the "Bench lands" of the Smoky or Unaka Mountains. If this statement be correct, it probably points to a western extension of the diamond belt of North Carolina, or to the transportation of the stones thence by streams.\*

Franklin County is far removed, both geographically and geologically, from all the other points above noted; and indeed in both aspects, a possible relation is suggested rather with the celebrated Manchester, Virginia, diamond. In both these cases, if the diamonds came from the Blue Ridge, they must have been carried a long distance by streams. There is, however, a possible nearer source, in the belt of "Atlantic" or "Tide-water" gneiss, which runs down from New York to and through the Carolinas, forms the rapids in the James at Richmond, and goes on directly toward Franklin County, North Carolina. This is merely a suggestion, however, caused by the geographical isolation of these two occurrences; nowhere else along this gneissic belt have diamonds ever been found.

\* *Gems and Precious Stones of North America*, by Geo. F. Kunz, New York, 1890, p. 21. 8vo, 363 pp.

\* *l. c.* p. 35.

## CHAPTER III.

### CORUNDUM GEMS.<sup>1</sup>

While diamonds and gold are found in the Piedmont country east of the mountains, North Carolina's chief corundum rocks are in Madison, Buncombe, Haywood, Jackson, Macon, and Clay counties, where numerous occurrences are known. A second and a third line of localities are recognized, but they are of slight importance. There are occurrences of corundum, however, east of the mountains, in the counties of Gaston, Lincoln, Burke, Iredell, Guilford, and Forsyth. The late Prof. John A. Humphreys called attention to some of these in 18—, in his paper No. 12 of "Natural History Notes on Western North Carolina," and suggested their possible importance in comparison with those farther west. Some of the earliest specimens, also, were collected in Gaston and Lincoln counties, as will be noted further on. But the main corundum region is beyond the Blue Ridge, where it forms a belt or zone of large extent, stretching along the whole course of the Southern Appalachians. The principal corundum gems are the ruby, sapphire, and oriental emerald.

According to Dr. Thomas M. Chatard,<sup>2</sup> of the United States Geological Survey, the corundum region extends from the Virginia line through the western part of South Carolina, and across Georgia as far as Dudleyville, Ala. Its greatest width is estimated to be about 100 miles. This belt has sometimes been called the chrysolite or chromiferous series, owing to the presence of chrysolite containing chromite, from the former of which corundum was believed, by certain authorities, to have been derived by alteration.<sup>3</sup> In this decomposed and altered chrysolite (dunite) throughout the Southern States, corundum is found in place; and the earlier writers on the subject, including such eminent authorities as Dr. J. Lawrence Smith and Prof. Charles U. Shepard,<sup>4</sup> believed it to be confined to the serpentinous rocks of this belt, which represent largely an al-

<sup>1</sup> For more detailed descriptions of corundum occurrences in North Carolina, reference is made to Reports, N. C. Geol. Survey, Vol. I, 1905, on Corundum and the Basic Magnesian Rocks of N. C., by Joseph Hyde Pratt and Joseph Volney Lewis; Corundum and the Basic Magnesian Rocks of N. C., by J. Volney Lewis, Bull. No. 11, 1895; and also Gems and Gem Mining in the South, by Joseph Hyde Pratt; The Southland, Vol. I, Nos. 3 and 4, 1901.

<sup>2</sup> Mineral Resources of the United States, p. 714, 1883-1884.

<sup>3</sup> See Corundum: Its Alterations and Associated Minerals, by Frederick A. Genth, in Contributions from the Laboratory of the University of Pennsylvania, No. I, Philadelphia, 1873.

<sup>4</sup> Corundum and Its Gems: A Lecture before the Society of Arts, Boston, 1876.

teration product of chrysolite. Such was the general view during the years following the Civil War, when the mineral resources of North Carolina were beginning to be actively developed.

More recently, it has come to be seen that this is only one phase of corundum occurrence, although much the most conspicuous. The investigation of the Geological Survey, conducted by Dr. Joseph H. Pratt,<sup>\*</sup> and Prof. Joseph Volney Lewis,<sup>†</sup> have traced several distinct associations in which corundum appears. Three of these are clearly developed in North Carolina:—(1) In the crystalline schists, as long prismatic crystals, usually opaque, grey, pink, or blue; (2) in the decomposed chrysolite or peridotite rocks, called dunites, that intersect the schists, as igneous intrusions; the crystals often large and variously colored, but very rarely of gem quality; (3) in more or less decomposed basic rocks, with garnets, in the Cowee Valley in Macon County, where the crystals are small, in six-sided tables or to some extent rhombohedral, sometimes transparent and rich red. These last are the "Cowee rubies." The second group corresponds to the chrysolite or serpentine occurrence noted by the earlier writers; the first has been but recently distinguished with clearness from the second. It appears now, through further researches of Dr. Pratt that under this first head are again included two very different modes of geological occurrence,—one in a hornblende gneiss arising from the alteration of an igneous rock and its foliation by pressure, and the other in a true gneiss varying to a quartz schist, which has resulted from the metamorphism of sedimentary strata. These latter gneisses occur separately, extending along the crest of the Blue Ridge, at an elevation of 3000 to 4000 feet, from Rabun County, Georgia, to Clay County, N. C. The corundum appears in irregular bands in the gneiss, evidently belonging to it, and not in veins or dikes. Dr. Pratt concludes that these were originally aluminous shales, and that in the long process of metamorphism, the alumina may have first separated as bauxite (hydrated oxide), and subsequently formed corundum bands parallel to the planes of lamination.

In all the other cases, the corundum is a product of true igneous action, having either crystallized out from a molten rock directly, or formed at the contact zones of such rock with others which it penetrated, by mutual chemical actions under the influence of great heat. The former is a frequent manner in which corundum exists. The extensive deposits lately made known in Ontario, are in a nepheline-syenite, plainly igneous in

<sup>\*</sup> Amer. Jour. Sci., Vol. VI, Pt. 4, p. 59, 1898; Vol. X, pp. 295-298, 1900.

<sup>†</sup> N. C. Geol. Survey, Bull. 11, 1896 and Vol. I, 1905.

origin, and the gem corundums of Montana are derived from intrusive dikes. The occurrence in crystalline limestone, in northern New Jersey, like that in Burma, is probably of the other type, a result of contact metamorphism, although Messrs. Brown and Judd have advanced a theory for the Burman mines, that attributes even these to an original igneous source.

The whole question of the geology of corundum,—its origin, mode of formation, etc., has been obscure and uncertain for a long time. Many theories have been advanced, only to be modified by subsequent discoveries. Within a few years past, however, important progress has been made; and though much remains to be ascertained, a number of points have gradually been established.

Among these is the fact that corundum, long regarded as a somewhat rare mineral, is really of more frequent occurrence than was formerly supposed; and also that it has been formed under various conditions and in several distinct ways. As already stated above, it is now known to have been produced (1) by crystallizing directly out of igneous rocks; and (2) by various forms of alteration and metamorphism, in both igneous and sedimentary rocks. The first head is further divided into occurrences in basic and in acidic rocks, and again into cases when the alumina was present in excess in the igneous rock itself, as an original constituent (autogenic), and those when it was introduced in pieces of an aluminous shale traversed by the igneous rock and taken up by it in its ascent (allothigenic). All these cases of occurrence have now been fairly identified in the corundum localities in the United States.

The earlier writers generally held that pure alumina (corundum) was a secondary or derivative mineral, formed by the alteration of other species in which it had previously existed in combination, as a silicate. Its close association with the altered peridotite or chrysolite (dunite) belt of the South Atlantic States, has already been referred to, and the belief of some geologists that the corundum was derived from the chrysolite, by various processes of alteration. The late eminent Dr. F. A. Genth, while not committing himself to any positive statement as to the origin of the corundum, developed a remarkable body of facts as to the alteration of corundum itself into various other and associated minerals.<sup>7</sup> There is not space here to go into any full outline of the course of observation and opinion. This has been very well done by Dr. J. H. Pratt, of the North Carolina Geological Survey, in his recent paper "On the Origin of the Corundum associated with the Peridotites in North Carolina."<sup>8</sup> In thi

<sup>7</sup> The Alterations of Corundum; Proc. Am. Phil. Soc., XIII, pp. 361-406, 1878.

<sup>8</sup> Am. Jour. Sci., IV, Vol. VI, No. 31, July, 1898, pp. 49-65.

article he shows how the igneous origin of these peridotites or dunites has come to be gradually established, and the separation of the corundum from them as an original ingredient. In a subsequent and more extended paper on "The Occurrence and Distribution of the Corundum in the United States,"<sup>\*</sup> Dr. Pratt describes all the known localities, and the special features of each.

A full and excellent account of the distribution, the geology, and the history and literature of corundum, with special reference to Georgia, has also been given by Prof. Francis P. King, assistant geologist of that State, in his "Preliminary Report on Corundum Deposits in Georgia."<sup>†</sup>

The earliest discovery of corundum in the United States was reported in 1819, by Mr. John Dickson, in an article on the mineralogy and geology of the two Carolinas, published in "Silliman's Journal."<sup>‡</sup> The crystals which he obtained came from Laurens District, S. C., a locality which has since yielded a considerable amount of both corundum and zircon.

Of corundum in North Carolina, the first recorded account is the statement by Prof. C. D. Smith, who was the assistant State Geologist under Professor Emmons, that it was found in 1846, but he does not say where or by whom. Dr. F. A. Genth reports that a large mass of corundum was obtained in 1847, in Madison (then a part of Buncombe) County, on the French Broad River, 3 miles below Marshall.

This was a dark blue piece, associated with chlorite and margarite. In 1849 or 1850, Prof. Charles U. Shepard received from Gen. Thomas L. Clingman several pounds of a coarse blue sapphire broken from a large crystal "picked up at the base of a mountain on the French Broad River in Madison County, N. C." This is probably the same discovery as that previously noted.

Whether the Indians knew anything of corundum is uncertain. It is too hard for them to have worked it in any way, and it has not been recognized among any of the minerals occasionally found in graves or mounds. As Professor King of Georgia says, it is not unlikely that some of the pink or blue fragments of crystalline corundum found in the gravels of the Southern States may have been noticed and prized as ornaments; but the aborigines certainly made very little use of it otherwise. A curious fact is noted by Professor King, however, in reference to the corundum mine at Track Rock, in Union County, Georgia,—that near the locality is a rock covered with curious carvings, many of them resembling animals tracks, whence the place derives its name.

<sup>\*</sup> U. S. Geol. Survey Bull., No. 180, 93 pp., 1901, and Bull. 269, 175 pp., 1906.

<sup>†</sup> Geol. Survey of Georgia, Bull. No. 2, 133 pp., 1894.

<sup>‡</sup> Am. Jour. Sci., I, Vol. III, p. 4.

Possibly the Indians may have employed fragments of corundum in executing these designs on the rock (?).

This first recognition, far to the west, was soon followed by some on the eastern side of the Blue Ridge. In 1852, Prof. R. T. Brumby, of the College of South Carolina, collected specimens of corundum at Clubb (now Chubb) Mountain, in Gaston County, and placed them in the cabinet of the College, where they still remain, with Professor Brumby's dated labels. They are rough crystals and crystalline masses, of dark blue color, covered with the micaceous alteration-products so frequently present; but they have high interest in being perhaps the first North Carolina specimens to be determined, labeled, and placed in a public collection. About the same time Dr. C. L. Hunter discovered corundum in Gaston County, perhaps at the same locality, and Professor Emmons referred to it in his report on the midland counties of North Carolina in 1853.<sup>12</sup> The Civil War began soon after, putting a stop to further research, and it was not until its close that investigations were resumed.

Rev. C. D. Smith, of Franklin, N. C., who in his former position on the State Geological Survey, had become very familiar with the minerals of the State, now discovered most of the important localities in North Carolina. In 1865 a specimen was brought to him from a point west of the Blue Ridge, which he recognized as corundum; he visited the locality, collected specimens, and announced the occurrence. This was the origin of the mining industry now so valuable. These discoveries led to further exploration, and many localities were found in the same region, which have since been more or less developed.

In 1870, Mr. Smith sketched the corundum belt of North Carolina, as running in a southwesterly course across Macon County, where it strikes the Georgia State line, its general direction coinciding with the trend of the Blue Ridge, until it reaches the head of the Tennessee River, when it suddenly ceases on encountering the Nantahala Mountain (a spur of the Blue Ridge here running due north), to reappear 10 miles to the northwest on Buck Creek, whence it pursues its original course of northeast and southwest across the Chunkyal mountains, where it again enters the Blue Ridge. Later investigation has revealed a more extended belt.

Two of the localities in this region have been much the more prominent,—those at Corundum Hill and Buck Creek.

With the opening of the Culsagee (Cullasagee, or Cullasaja) mine, on Corundum Hill, near Franklin, Macon County, by Mr. C. W. Jenks, in

<sup>12</sup> Amer. Jour. Sci., II, Vol. XV, p. 373, May, 1853.

1871, the first systematic attempt to mine gems within the State was begun. From a scientific point of view the operations were most interesting, but the number of gems found did not warrant permanent operations, for gems only, and after a few years mining for this mineral was for abrasive purposes.

This mine, which includes several openings, is situated on the Culsagee or Sugartown Fork of the Little Tennessee River, 8 or 9 miles above (southeast of) the town of Franklin, the county seat, at an elevation of about 2500 feet above the sea. The Corundum Hill is essentially an outcrop of peridotite (dunite), some 10 acres in area, and rising to a height of between 300 and 400 feet. Most of the openings are along the contact of the dunite with the gneiss or schist through which it rises, and follow "contact veins" of corundum. It has often been called the Jenks mine, also the Culsagee and the Corundum Hill, names derived from the locality and from the name of its first operator, Charles W. Jenks, of Boston, Mass. It was subsequently worked by the Hampden Emery Company, of Chester, Mass., under the direction of Dr. S. F. Lucas, and became known as the Lucas mine. It is now owned by the International Corundum & Emery Co., of New York, which also controls several other less important mines in the same neighborhood.

The other prominent locality was the Buck Creek or Cullakenee (also spelled Cullakeenee and Cullakenish) mine, in Clay County, 20 miles southwest of Franklin. It was opened soon afterwards, and has had a similar history. The outcrop is much more extensive, but less work has been done there.

These mines, especially the first, have been described in various scientific papers and reports. One of the earliest published accounts was given by Prof. C. U. Shepard<sup>13</sup> in 1872; another was by Mr. Jenks himself, 2 years later, in a paper read before the Geological Society of London. In 1876, Prof. Rossiter W. Raymond read an excellent paper before the American Institute of Mining Engineers<sup>14</sup>; in 1883, Dr. Thomas M. Chatard, of the U. S. Geological Survey described it again.<sup>15</sup>

Besides these valuable articles, there are no less excellent references in various reports of the State Survey, by Prof. W. C. Kerr, and in articles by Dr. F. A. Genth, who was associated with him in portions of the survey work, and by Dr. J. Lawrence Smith.

Professor Shepard described the dunite rock very well, and recognized it distinctly as an altered form of chrysolite, referring it to the species

<sup>13</sup> *Am. Jour. Sci.*, II, Vol. IV, Aug.-Sept., 1872.

<sup>14</sup> *Trans. Am. Inst. Min. Eng.*, Chattanooga meeting, May, 1876.

<sup>15</sup> *Mineral Resources of the U. S.*, 1883-1884, p. 714.



known as villarsite. Dr. Raymond fully perceived its character as an igneous intrusion, differing from some other writers on this point, since clearly established. Dr. Chatard describes the Culsagee outcrop as consisting of chrysolite (dunite) mingled with hornblende. The corundum is enclosed among various hydromicaceous minerals, commonly grouped under the term chlorite, between the gneiss and the dunite, from the alteration of which they have evidently been formed. It occurs chiefly in crystalline masses, often of considerable size, and sometimes suitable for gems (Pl. IV, A). At other parts of the mine it is found in small crystals and grains mingled with scales of chlorite, forming what is called the "sand vein." This is so loose and incoherent that it is worked by the hydraulic process; and the small size of such corundum is the saving of much labor in the next process of pulverizing. At Buck Creek the chrysolite rocks cover an area of over 300 acres, and from that point southward the hornblende rocks assume greater proportions, being associated with albite instead of the ordinary feldspar and forming an albitic cyanite rock. There is also found here the beautiful green smaragdite, called by Professor Shepard *chrome-arfvedsonite*, which, with red or pink corundum, forms a beautiful and peculiar rock curiously resembling the eclogite or omphacite rock of Hof, in Bavaria, as Professor Shepard had noted in his early article in 1872.

Both these localities have also been recently described, with maps, in the admirable report of Dr. J. H. Pratt and Prof. J. V. Lewis, elsewhere referred to.<sup>16</sup>

The resemblance in the occurrence of the North Carolina corundum to that of Mramorsk in the Ural Mountains, as described by Prof. Gustav Rose of the University of Berlin, has been shown by Professor Genth.<sup>17</sup> There the associated species are serpentine and chlorite schist, sometimes with emery, diaspore, and zoisite, very similar to the chrome serpentine corundum belt of the Southern States. The emery deposits of Asia Minor and the Grecian Archipelago, according to Dr. J. Lawrence Smith,<sup>18</sup> yield that substance in marble or limestone, overlying gneissic rocks; while with it are associated many of the same hydromicaceous and chloritic species that accompany both the New England emery and the southern corundum.

With more particular reference now to the actual gems yielded at the various localities, we may note that they occur in two distinct forms: first, as crystals, of which the usual forms for sapphire are doubly term-

<sup>16</sup> Corundum and the Peridotites of North Carolina, N. C. Geol. Surv., Vol. I, 1905 —

<sup>17</sup> Contributions to the Laboratory of Penn. Univ., No. 1, 1873.

<sup>18</sup> Am. Jour. Sci., II, Vol. X, p. 355, Nov., 1850; and Vol. XII, p. 53, Jan., 1851.



A. TRANSPARENT BLUE AND GREEN SAPPHIRE, NATURAL SIZE, MACON COUNTY, N. C.



B. CORUNDUM, SHOWING ALTERATION, NATURAL SIZE, HAYWOOD COUNTY, N. C.



nated hexagonal pyramids, often barrel-shaped by the occurrence of a number of pyramidal planes of successively greater angle; and second, as nodules of purer and clearer material, in the midst of larger masses of ordinary cleavable corundum. These, when broken or falling out, are sometimes taken for rolled pebbles, which they resemble. This latter, and quite peculiar mode of occurrence is treated of somewhat in the able paper on this mine, read by Prof. Rossiter W. Raymond, in May, 1876, before the American Institute of Mining Engineers, and published in their Transactions.

In regard to the relations of different kinds of corundum, Dr. Pratt says:—"The corundum gem or sapphire localities are usually distinct from corundum localities, although very handsome gems have been found where corundum was mined for abrasive purposes, notably at the Corundum Hill mine."<sup>1</sup>

In 1874, Mr. C. W. Jenks read a paper on the occurrence of sapphires and rubies *in situ* in corundum, at the Culsagee mine, before the Geological Society of London; in this brief but important article he described the location and mineralogical character of the mine, and the fact of the presence of portions in the corundum of true gem quality. The paper attracted much interest, and Prof. David Forbes said that great credit was due to Mr. Jenks, and that he had "discovered the actual home" of the true ruby and sapphire, which had never before been really traced to their sources (see Pl. I).

Some years later, a London periodical made the statement that any one who found the sapphire or the ruby in its original matrix would be called the "King of Rubies," and that his fortune would be assured. But such is not always the result to those who deserve it. Mr. Jenks was undoubtedly the original finder of the true corundum or sapphire gems in place, and he obtained from this locality nearly all the fine crystals of the best American collections. One of the most interesting of these is a piece of blue corundum with a white band running across it and a place in the center where a nodule had dropped out. This piece was cut and put back in its place, and the white band can be seen running across both gem and rock. (See colored Pl. 1.) Nearly all the fine gems from Franklin, N. C., were brought to light by Mr. Jenks' mining; but although found in their original matrix, they were of such rare occurrence that it was found unprofitable to mine for them alone. The work was subsequently suspended for some time in consequence of the financial crisis of 1873, but resumed by the Hampden Emery Company.

<sup>1</sup> Corundum in the United States, J. H. Pratt, 1901, p. 10 (Bull. No. 180, U. S. Geol. Survey).

The largest crystal ever found, which is 5 times larger than any other known, is one early discovered by Mr. Jenks and described by Professor Shepard.\* It is now in the cabinet at Amherst College; but much injured by the disastrous fire of 1882, which destroyed so many fine specimens of the Shepard collection. It weighed 312 pounds, and measured 22 inches in length, 18 inches in breadth, and 12 inches in thickness. In form it was a steep and somewhat irregular six-sided pyramid, terminated above by a rather uneven basal plane. Its general color is grayish blue.

In addition to these and other notable crystals, many public collections, besides the American Museum of Natural History (which possesses much the finest series), contain numerous cut gems from this mine.

A blue stone of over 1-carat weight is in the United States National Museum at Washington, and a series of fine red and blue crystals have been deposited there by S. F. Lucas. In the collection made by the late Prof. Joseph Leidy, of Philadelphia, and now also in the National Museum, are several gems from the same mine, including a wine-yellow sapphire of  $3\frac{1}{4}$  carats (660 milligrams); a violet-blue stone of a little over 1 carat (215 milligrams); and three dark-blue ones weighing respectively about  $1\frac{1}{2}$  (320 milligrams);  $1\frac{1}{4}$  (250 milligrams); and  $\frac{3}{4}$  (145 milligrams) carats each.

In Dr. Spencer's notes on American gems in the British Museum of Natural History, London, is noted a specimen of corundum from Corundum Hill, Macon County, N. C., which consists of a rough hexagonal prism, 26 cm. long and 18 cm. across, of a reddish color.

In a recent report of Prof. J. H. Pratt, State Geologist, he thus refers to gems from this locality:

At the Corundum Hill Mines, Cullasagee, N. C., various shades of green ruby corundum have been found. Two of the best rubies of good color that have ever been found at this mine are in the collection of Clarence S. Bement, of Philadelphia; there are also a number of fine ones in the United States National Museum at Washington. Many of the smaller crystals of various shades of pink to red are transparent near the outer surface and near their extremities, and from these small gems can be cut, but few that are worth \$100 have been obtained from them.

Probably the finest emerald green colored sapphire in the world came from the Cullasagee mine sand is now in the Morgan-Bement collection at New York. This is the rarest of all the colors of sapphire or corundum gems, and is known as Oriental emerald. The specimen is a crystal

\* Am. Jour. Sci., IV, Aug. and Sept., 1872.

$1 \times 2 \times 1\frac{1}{4}$  inches; part of it is transparent, and several very fine gems could be cut from it, see Plate XII.

Another locality in the same county, interesting, though less prominent, is the Mincey mine on Ellijay (properly Elegée) Creek, about  $2\frac{1}{2}$  miles northeast of Corundum Hill. Some good ruby corundum occurs here, together with a peculiar brown or bronze variety, known locally as "pearl corundum," which shows distinct asterism, both by natural and artificial light, when the stone is cut *en cabochon*. In natural light these corundums all show a bronze luster and are somewhat similar to the cat's-eye, but in artificial light the star is more distinct. Most of the bronze corundum is in rough crystals, but some have been found that have the prismatic faces smooth and well developed, and these are often dark, almost black, in color. One crystal of this dark kind, found some years ago, yielded gems  $\frac{3}{4}$  of an inch in diameter. A similar asterism has been noticed in many of the rubies and sapphires from Cowee Valley, and at several other points in the State. According to Von Lasaulx, it is sometimes produced by rifts due to the basal parting. These rifts when examined with the microscope, are seen to be very thin, sharp and rectilinear, and are parallel to the edge between the prism and the base. In other cases asterism is undoubtedly due to rutile or other minute crystals enclosed in the corundum, intersecting each other at an angle of  $60^\circ$ , or in some similar systematic positions.

At the Cullakenee mine, Buck Creek, in Clay County, masses of emerald to grass-green amphibolite (also called smaragdite) are found, through which are disseminated particles of pink and ruby corundum, from the size of a pea to some as large as hickory nuts. The corundum is not of gem quality, but the combination of the green and pink makes very beautiful specimens, and as the rock is hard enough to take a good polish, it might furnish a decorative or ornamental stone of some value. It has been introduced for such purposes under the name of ruby matrix.

A similar association of green amphibolite with corundum, sometimes pink and sometimes dark blue, is found near Elf post-office, on Shooting Creek, in the same county. Other corundum localities in Clay County are the Foster mine, near the headwaters of the north fork of Shooting Creek, and the Herbert mine on Little Buck Creek.

Of late much attention has been aroused by the discovery of rich ruby corundum in small distinct crystals of a different character from any others found in the State, and in a different rock. These have been known as the Cowee rubies, from the locality in the Cowee valley, in Macon County. It has seemed as though here, at last, true gem rubies, equal to those of Burma, had been really found, and much interest has been felt in

the discovery. Thus far, however, no very important results have been obtained, although some of the stones are unquestionably fine, but most of them are small (see Pl. I).

They are unusually interesting and beautiful as crystals, but many of them are imperfect. It is claimed, however, that the percentage of imperfect stones is no greater than it is in the rubies from Burma. Unfortunately, many of the crystals also have inclusions which mar their elegance as gems. The exact locality of this very interesting occurrence is a tract of some 10 square miles lying between Mason's Branch and the Caler Fork of Cowee Creek, affluents of the Little Tennessee River some 6 miles below Franklin, Macon County. Many interesting minerals are found in this area, and there are mica mines there, and mines where the abundant garnet has been worked for use as an abrasive. The beautiful rhodolite garnets, found in close association with the ruby crystals in the gravel and saprolite, will be described separately under garnet.

The discovery and development of the "Cowee rubies" were first described in the volumes of the U. S. Geological Survey (Mineral Resources of the United States), in the writer's annual reports on the Production of Precious Stones, from 1893 to 1896, year by year, and further in that of 1899.<sup>21</sup> Also in 1899, there appeared a full account by Prof. J. W. Judd, Mr. W. E. Hidden, and Dr. J. H. Pratt<sup>22</sup>; and the latter gentleman has since published further accounts in his annual reports, and in his special bulletins on corundum in the United States.

The first published notice in the author's report for 1893, above mentioned, was of the finding of ruby corundum, in small hexagonal crystals, flat or tabular, in an alluvial deposit on the Reeves farm, not far from Franklin, associated with beautiful garnets. The next year's report described the locality as consisting of the valley of a stream, for several miles, in which the rubies were distributed through a gravel bed from 2 to 10 feet thick, overlain by several feet of surface deposit,—a mode of occurrence very similar to that in the Mogok Valley in Burma, where the finest rubies are obtained.

The attention of the author was first called to these rubies by the late Mr. James D. Yerrington, of New York, who had specimens, both cut and uncut, that he had received from Mr. Reeves, of Athens, Georgia, who owned the farm on which they had been found. Two cut gems of  $\frac{1}{2}$  a carat each, were set in a flag scarf-pin shown in the Tiffany jewel-

<sup>21</sup> Mineral Resources U. S., Ann. Reps. U. S. G. S., 1893, 1894, 1895, 1896, 1899.

<sup>22</sup> Am. Jour. Sci., IV, Vol. VIII, Nov. 1899, pp. 370-380.

<sup>23</sup> Bulls. U. S. Geol. Survey, No. 180, 1901 and No. 269, 1906.

exhibit at the Columbian Exposition of 1893; these were subsequently unmounted and displayed by the same firm at the Atlanta Exposition of 1895. They now form part of the Tiffany-Lea collection, included in that of the U. S. National Museum at Washington. A number of others (see figures), obtained at about the same time, are in the American Museum of Natural History, New York. A fine series, both of crystals and cut gems, was shown by the North Carolina Geological Survey at the recent Expositions at Buffalo, 1901, Charleston, 1901-02, and St. Louis, 1904.

In 1896, the locality was visited and examined by Mr. C. Barrington Brown, the eminent authority on ruby mining, who had previously prepared an exhaustive report on the Burma region, in conjunction with Prof. J. W. Judd, for the British Government.

In 1899, as above stated, Professor Judd and Mr. William E. Hidden published a joint article, with crystallographic notes by Dr. J. H. Pratt. This account embodied the results of Mr. Brown's visit, of Mr. Hidden's operations on the ground, and of Dr. Pratt's studies on the crystal forms and their relations. It had now become clear that the rubies from this locality occurred in a wholly different association from any other corundum in the State, and the title of the article was "On a New Mode of Occurrence of Ruby in North Carolina." The surrounding rocks are schists and gneisses, often containing corundum, but in elongated crystals and not of gem quality. Only a few miles away are the dunite outcrops of the Culsagee and other localities, already described. But at Cowee the rock is wholly different, and the forms of the crystals also. The first accounts had reported a limestone as the probable source of the valley deposit, and even as the matrix of the crystals, as is the case in Burma. But further study had disproved this statement. Underneath the ruby-bearing gravel, comes a soft decayed rock to which the name of saprolite has been given,—a result of the decomposition of basic igneous rocks, in place. This is sometimes many feet in thickness, but gradually passes downward into the unaltered condition of the same rocks. Trial shafts show that this change begins from a depth of some 35 feet, when portions of the unaltered rock begin to be met with. The original rock, when reached, proves to consist of several related varieties, comprising amphibolite, hornblende-eclogite (garnet-amphibolite of some authors), and a basic hornblende-gneiss, with some feldspars (labradorite and perhaps anorthite). Some of these rocks are doubtless the source of the rubies strewn through the saprolitic material and the overlying gravel, though their actual occurrence in the undecomposed rock has not yet been proved. The crystals are distinct from any others found in North Carolina, but



resemble in form those from Yogo Gulch, Montana (the sapphire variety) which are taken from true igneous dikes; and these flat and tabular hexagonal forms are regarded by students of crystallography as characteristic of corundum that has solidified from a molten igneous rock.

Another corundum occurrence in saprolitic rock, but the crystals blue and more prismatic, is noted by Dr. Pratt at the Reed, or Watauga mine, 6 miles east of Franklin; and red, sometimes ruby, corundum is found in old stream gravels near West Mills; both of these are in Macon County. A number of minor occurrences are known throughout the general region, where there are small saprolitic areas.

There are many other localities of corundum in this group of counties, some of the more important or promising of which may be simply mentioned here. In Macon County, besides the important occurrences already described, corundum appears at Glenville, in chlorite schist; at Nona, on Thumping Creek, in nodules and flat crystals in gneiss; on Hickory Knoll Creek at an elevation of 4,000 feet on Fishhawk Mountain, in dunite; and at the Coweeta mine, of pink color in greenish cyanite. Of late, the emery variety has been found, and to some extent worked, at several points near Fairview Knob, in a basic magnesian rock, the principal mine being the Fairview, near North Skeener Gap, and the Waldroop mine on Dobson Mountain.

Jackson and Transylvania counties have numerous corundum localities, notably in the region along their border, where the town of Sapphire has been named, and the appellation of the Sapphire country is frequently used. Here are found many outcrops of peridotite, with a general N.E.-S.W. course, and frequently associated with corundum. One locality that gives some promise is the so-called gem mine on the property of Dr. Grimshawe, of Montvale. This has been known and to some extent worked, for many years. Rubies of good color, from which a number of fine but very small stones have been cut, have been found here in the gravels of the stream, together with blue and yellow corundum of gem quality. By following up the gravels the corundum was located in a small vein in the decomposed peridotite.

At the Sapphire and Whitewater mines, near Sapphire, fragments of corundum of a fine blue color have been found, from which small but good gems have been cut.

Quite large amounts of commercial corundum have been taken out at the Bad Creek and Socrates mines, and also at the Burnt Rock and Brockton mines; these two are in Transylvania County, the others being in Jackson County, and all in peridotite. Other associations in Jackson County are, along Caney Fork and Chastain's Creek, in chlorite schist; and at Bett's Gap in translucent grayish-white crystals in gneiss.

In Haywood County, 2 miles northeast of Pigeon river, near the crossing of the Asheville road, and 2 miles north of this, on the west fork of Pigeon River, at Presley mine, are found some of the finest colored specimens of blue and grayish-blue corundum, in a pegmatitic dike, and also near Retreat post-office (see Pl. IV, B). At Newfound Gap, red corundum occurs in an outcrop of dunite.

Twenty miles northeast of the Presley is the Carter mine in Buncombe County, where fine white and pink corundum occurs in crystals and in a laminated form in peridotite. Blue, bluish-white, and reddish varieties occur at Swannanoa Gap; and also a little south of the town of Democrat, corundum appears,—all in the same or similar rock.

Yancey County has several localities, the most noted of which are Celos Ridge, 8 miles southeast of Burnsville, where crystals occur in a decomposed gneiss, and Egypt, 10 miles west of the same town, where white crystals, sometimes mottled with blue, are found directly in the decomposed peridotite (dunite). This occurrence is noted as of much interest, by Lewis<sup>1</sup> and Pratt,<sup>2</sup> for although corundum is very largely associated with the rock, the crystals are rarely found actually enclosed in it.

Northeast of these mines, in the line of strike of the whole country rock, corundum is found in gneiss near Bakersville, in Mitchell County; and also southwest, in Madison County, near Marshall, a little north of where Big Ivy River enters the French Broad; here the rock is amphibolite.

Grouped together under the name of the Blue Ridge tract, are a number of localities where the corundum occurs in long bands of quartzose schist that belong in and with the gneisses among which they occur. This was referred to before as a very distinct mode of occurrence, in that the rocks are altered sediments, and the corundum, a product of metamorphic action rather than igneous. These corundiferous schists have been traced for many miles along the crest of the Yellow and Chunkygal mountains. The content of corundum is very small, and these deposits will not be important sources for some time to come. Dr. Pratt makes 4 local divisions;—The Scaly Mountain tract, at an elevation of some 4,500 feet on the southern and southwestern slopes of those mountains, near the headwaters of Beech Creek, a tributary of the Tallulah; the Foster tract, just over the line in Georgia; the Yellow Mountain tract, on the northern slopes of those mountains; and the Chunkygal tract, near the headwaters of Sugar Cove Creek, on the western slopes of the mountains. The first

<sup>1</sup> Bull. 11, N. C. Geological Survey.

<sup>2</sup> Bull. 269, U. S. Geological Survey.

two have been worked somewhat, by the Corundum Mining & Manufacturing Co., of Philadelphia. These localities are all near the southern border of the State, and pass over into Rabun County, Georgia.

*The Piedmont Counties.*—As was stated above, corundum was early found at some points east of the mountains; and the references to discoveries and collecting by Dr. C. L. Hunter, Prof. J. A. Humphreys, and Prof. Brumby of Columbia, S. C., antedate the Civil War by about 10 years. Since the new epoch of mineral development set in after the return of peace, further discoveries have been made, all of interest, but none as yet of importance. Mr. J. A. D. Stephenson obtained fine hexagonal prisms of pale brown corundum at Belt's Ridge, near Statesville, Iredell Co., and some crystals of fine colors from other neighboring points. Prof. Lewis mentions a black corundum in amphibolite, on the Hunter farm, 8 miles north of Statesville, another occurrence in the same rock, at the Acme mine, and a pink corundum in cyanite at the Collins mine, both in the same vicinity. An old locality, especially noted by Professor Humphreys, is Shoup's Ford, in Burke Co., where the corundum is associated with fibrolite, which sometimes surrounds or encloses the crystals, forming what Professor Humphreys described as "pods." In Gaston County, blue corundum occurs with quartz and mica, at Crowders Mountain and Chubbs Mountain; the latter is the source of the Brumby specimens in 1852; it was then known properly as *Clubb* Mountain, named from an old resident and Revolutionary patriot.

Corundum in grayish-blue crystals in garnet-bearing schists and gneisses is reported from points along the ridge stretching from Carpenter's Knob, northwest, on the borders of Burke, Catawba, and Cleveland counties.

## CHAPTER IV.

### GEM MINERALS OF THE PEGMATITIC DIKES.

In the pegmatite veins of North Carolina are found so many minerals of gem value<sup>1</sup> that a short description of these dikes is given here.

These pegmatitic veins are interesting not only from a commercial standpoint on account of the value of the mica obtained, but also from a mineralogical standpoint on account of the variety of minerals that they sometimes contain.

In character these pegmatitic dikes are very similar to a granite and have sometimes been called "coarse granite" and, if we could conceive of the constituents of a granite magnified a hundred times or more, we would have an appearance that is very similar to a pegmatitic dike. The main mineral constituents of these dikes are quartz, feldspar, and muscovite mica in varying proportions, sometimes being nearly equally distributed while in others sometimes one and again another will predominate. Sometimes the feldspar, quartz, and mica have separated out in rather small masses while at other times they have separated out on a larger scale and are more or less crystallized.

The associated minerals that occur in these dikes vary with their occurrence and while in some there is a great variety of them, in others they are very rare. The pegmatitic dikes that are observed in North Carolina have furnished the greatest variety of accessory minerals, 45 having been observed from the different veins, at a number of which over 20 different minerals have been observed. Of these accessory minerals the garnet (either andradite or almandite) is by far the commonest and is often the only accessory mineral observed.

The accessory minerals in these pegmatitic dikes are usually well crystallized and a number of them are gem minerals. The following is a list of the minerals that have been identified in the mica-bearing pegmatitic dikes in North Carolina and they are given approximately according to their relative frequency of occurrence:

Quartz (massive, crystallized and smoky).	Zoisite (var. thulite). Menaccanite.
Albite, Feldspar.	Rogersite.

<sup>1</sup> Joseph Hyde Pratt in "The Southland," Asheville, North Carolina, August, 1901, pp. 120-121.

Microcline, Feldspar.	Hatchettolite.
Oligoclase, Feldspar.	Fergusonite.
Orthoclase, Feldspar.	Uraninite.
Kaolin.	Uranotil.
Beryl (Emerald, yellow, and aqua-marine).	Phosphuranylite.
Muscovite, Mica.	Monazite.
Biotite, Mica.	Zircon.
Essonite, Garnet.	Pyrrhotite.
Almandite, Garnet.	Hematite.
Andradite, Garnet.	Limonite.
Tourmaline.	Rutile.
Apatite.	Molybdenite.
Columbite.	Opal (var. hyalite).
Allanite.	Enstatite.
Epidote.	Actinolite.
Samarskite.	Cyanite.
Gummite.	Gahnite.
Autunite.	Chabazite. (?)
Pyrite.	Graphite.
Magnetite.	Pyrophyllite.

Of the minerals given in this list the following have been found of sufficient purity to be a source of gems:

Essonite.	Albite.
Almandite.	Oligoclase.
Beryl.	Orthoclase.
Quartz.	Gahnite.

The following of these pegmatite occurring minerals are precious stones:

Albite, Feldspar.	Quartz, (massive, crystallized and smoky).
Almandite, Garnet.	Menaccanite.
Beryl (Emerald, yellow, and aqua-marine).	Microcline.
Cyanite.	Oligoclase, Feldspar.
Essonite, Garnet.	Rutile.
Opal (var. hyalite).	Zircon.
Pyrite.	

The following are radio-active:

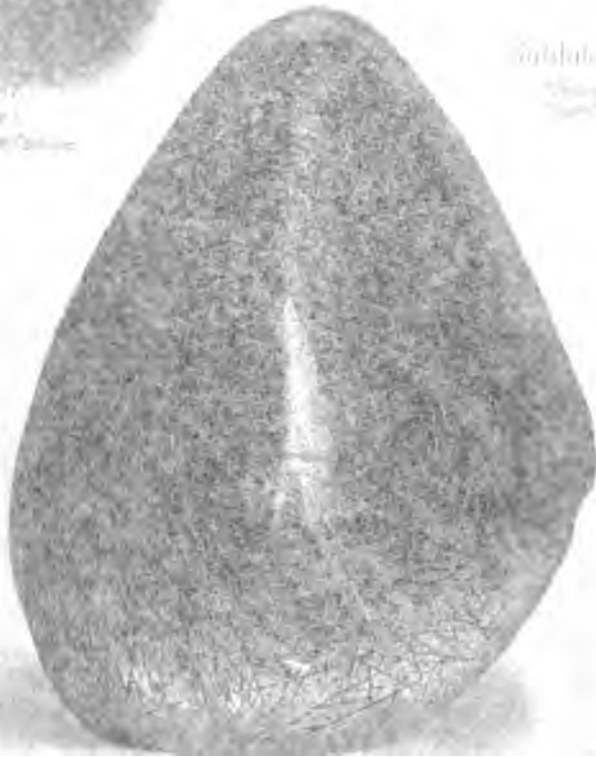
Allanite.	Monazite.
Autunite.	Phosphuranylite.
Columbite.	Rogersite.
Fergusonite.	Samarskite.
Gummite.	Uraninite.
Hatchettolite.	Uranotil.
Menaccanite.	



Smoky quartz  
 100 mm diam, weight 1.5  
 from the site, Mount Potosi



Smoky quartz  
 100 mm diam, weight 1.5  
 from the site, Mount Potosi



Smoky quartz



Smoky quartz





A  
Smoky quartz,  
(raining stone),  
Alexander County, North Carolina



E  
Rutlated Quartz,  
Alexander County,  
North Carolina



C  
Rutlated Quartz,  
Alexander County,  
North Carolina



D E  
Amethyst  
Henry, Lincoln County,  
North Carolina



F  
Amethyst,  
Tosony Creek,  
Smith Bridge Township,  
Macon County, North Carolina





The following are commercial minerals:

Graphite.  
Kaolin.  
Magnetite.

Muscovite (mica).  
Orthoclase.  
Pyrophyllite.

It is the breaking down of these veins that form many of the smaller often microscopic minerals found in the detritus of the gold veins.

#### THE FELDSPARS.

Several interesting varieties of feldspar occur in North Carolina, among which the following may be especially noted as the ones which are of importance as gem material.

*Orthoclase*.—A very interesting variety of sunstone was found by J. A. D. Stephenson at the quarry in Statesville, N. C.; the reflections are as fine as those of the Norwegian, but the spots of color are very small. Several hundred dollars' worth from this locality have been sold as gems.

*Microcline*.—This feldspar is closely related to orthoclase; it is sometimes of a very beautiful light green color, and is then known as amazon-stone, and valued for cutting and polishing for ornamental purposes. Several localities in North Carolina furnish this mineral, especially the Ray mica mine, Yancey County.

*Oligoclase*.—In December, 1887, specimens of feldspar were sent to the writer<sup>2</sup> by Daniel A. Bowman, who had found them at a depth of 380 feet in the Hawk Mica mine, 4 miles east of Bakersville, N. C. They proved to be a variety of oligoclase, remarkable for its transparency. The clearest piece measured 1 by 2 by 3 inches. One of the two varieties is of a faint window-glass green color, and contains a series of cavities, surrounded and fringed by tufts of white, needle-shaped inclusions called microlites; these tufts vary from 1/50 to 3/50 inch (0.5 to 1.5 millimeter) in diameter and are quite round, resembling those that are occasionally present in the Ceylonese moonstone. The wonderful transparency of the oligoclase and the whiteness of the inclusions give the whole mass a striking resemblance to the lumps of glass so commonly obtained from the bottom of a glass-pot. It was mistaken for this until its highly perfect cleavage was noticed. Recently some material of a slightly different character has been obtained at the mine. Cleavage masses of a white, striated oligoclase, 3 inches long, were found containing nodules about  $\frac{3}{8}$  inch to  $\frac{1}{2}$  inch (10 to 15 millimeters) across, which were as colorless and pellucid as the finest phenacite and entirely free from

<sup>2</sup> See Mineralogical Notes, by George F. Kunz, Am. Jour. Sci., III, Vol. XXXVI, p. 222, Sept., 1888.

the inclusions found in the greenish variety. This translucent variety, like the other, shows no striae.

The following analysis by Prof. Frank W. Clarke, made from a faint green variety, shows it to be a typical oligoclase. The specific gravity was determined to be 2.651. This has been cut into a transparent gem, and may be advantageously used for spectroscope, microscope, and other lenses.

Silica .....	62.60
Alumina .....	23.52
Ferric Oxide .....	.08
Manganous Oxide .....	trace
Lime .....	4.47
Potassa .....	.56
Soda .....	8.62
Loss by ignition .....	.10
	<hr/>
	99.95

*Labradorite (Opalescent feldspar).*—On the road to Charlotte, Mecklenburg County, and near Bakersville, Mitchell County, specimens showing a slight blue chatoyancy are found. This domestic labradorite is scarcely used at all in the arts, as the mineral from Labrador is cheaper and of a much superior quality, and takes a fine polish.

*Leopardite.*—This is a rock composed largely of whitish feldspar (orthoclase and plagioclase), spotted black, perhaps by manganese oxide, and named from its leopard-like appearance. It is abundant near Charlotte, Mecklenburg County, and also in Gaston County. It is not a definite mineral, but a variety of porphyry with disseminated crystals of quartz, and occurs in large masses as a rock, so that it would furnish a good ornamental stone, if polished. This variety of spotted feldspar is peculiar to North Carolina, and has been described in detail in the report on Building Stones.

The beryl, zircon, and other gem minerals, which are also constituents of pegmatitic dikes, are described in the following chapters.

## CHAPTER V.

### QUARTZ AND OPAL.

Quartz in its various crystalline forms,—rock-crystal, amethyst, and smoky quartz,—occurs at many points in North Carolina, and in some cases of fine quality (Pl. V). The non-crystalline varieties, such as agate, jasper, etc., have not, on the other hand, been found to any important extent in the State, until very recently in the chrysoprase workings near Asheville.

#### CRYSTALLINE VARIETIES.

*Rock-Crystal.*—Much interest was created in 1886, when a remarkable mass of rock-crystal, weighing 51 pounds, was sent to Tiffany & Company, New York. It purported to be from Cave City, Va., but was subsequently traced with certainty to the mountainous part of Ashe County, N. C.<sup>1</sup> The original crystal, which must have weighed 300 pounds, was unfortunately broken in pieces by the ignorant mountain girl who found it, but the fragment sent to New York was sufficiently large to admit of being cut into slabs 6 inches square and from half an inch to an inch thick. This superb crystal, if it had not been broken, would have furnished an almost perfect ball  $4\frac{1}{2}$  or 5 inches in diameter. It is now in the Morgan Collection at the American Museum of Natural History, New York. A visit to the locality by the author traced this specimen to the place of its discovery near Long Shoal Creek, on a spur of Phoenix Mountain in Chestnut Hill Township. There have also been found at 2 places, 600 feet apart (about 1 mile from the former locality), 2 crystals, weighing respectively 285 and 188 pounds. The larger of the 2 was 29 inches long, 18 inches wide, 13 inches thick, showing 1 pyramidal termination entirely perfect and the other less complete. All these crystals were lying in decomposed crystalline rock consisting of a coarse feldspathic granite, and were obtained either by digging or by driving a plow through the soil. Altogether several dozen crystals have been found in this vicinity weighing from 20 to 300 pounds each, and future working will undoubtedly reveal more. These large crystals are often very irregular and pitted, like many of those from St. Gothard. Of those now in

<sup>1</sup> Proc. Am. Assoc'n Adv. Sci., Vol. XXXV, p. 239, 1886.

the Morgan-Tiffany collection at New York, the most irregular was 20½ pounds in weight, with the entire surface rough and opaque like ground glass, and almost spherical in form, but the interior perfectly transparent. In a few instances, they had a coating of rich green chlorite that penetrated to the depth of an inch. This, when left on the quartz, gave the cut crystal, after polishing, the effect of a pool of water with green moss growing on the bottom.

Many beautiful articles have been made from this Ashe County material. One was an elegantly carved vinaigrette or scent-bottle, exhibited at the Paris Exposition of 1889. A crystal ball 5 inches in diameter, and a number of art objects, all of American workmanship, made from the same material, were shown at the Columbian Exposition at Chicago in 1893, and some of these are now in the Tiffany collection in Higinbotham Hall, in the Field Columbian Museum in that city. These were all made in the Tiffany ateliers in New York.

By far the most important piece from this locality, however, was a magnificent crystal obtained in 1888 by the author at the same locality. This was worked up into a special design, and exhibited as the finest piece of American lapidary work ever executed in rock crystal. It was the most important art object of stone at the great Paris Exposition of 1900, where it was shown by the makers, Tiffany & Company. It now will form part of the F. A. Matthiesen memorial gift, lately presented to the Metropolitan Museum of Art in New York City.

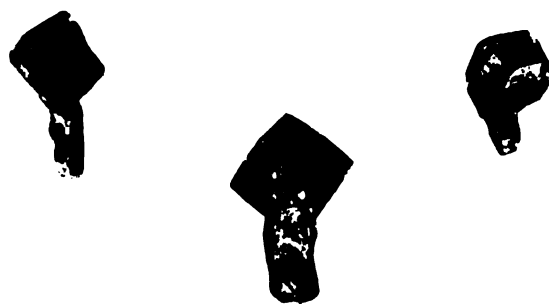
Another North Carolina locality was reported in 1896, by Mr. R. M. Chatham, who described crystals up to 40 pounds in weight, from Elkin, in Surrey County. Some large crystals are also known from South Carolina; and it is probable that a good deal of rock-crystal, capable of use in the arts, exists in the mountain region of the South.

The report of the finding near Bakersville of transparent crystals of quartz, weighing 642 pounds and 340 pounds respectively, was premature, as the specimens proved to be veins of translucent quartzite, with the crystalline markings of a group rather than of a single crystal. The clear spaces, which were to be observed only on these crystalline sides, would hardly afford material for a crystal ball an inch in diameter, and with this exception they are almost an opaque white, with flaws. Notwithstanding this error, it is certain that some localities in North Carolina have yielded larger masses of clear rock-crystal than any other State in the Union until the recent developments in Calaveras County, California.

In Alexander and Burke counties, N. C., crystals of white as well as smoky quartz have been found, in which were spaces that would cut in



A. QUARTZ CRYSTALS (SMOKY) NATURAL SIZE, ALEXANDER COUNTY, N. C.



B. AMETHYST, LINCOLN COUNTY, N. C.



clear crystal balls of from 2 to  $2\frac{1}{2}$  inches (Pl. VII, A). One of these from Alexander County, measuring  $2\frac{3}{16}$  inches, is in the State Museum of Natural History at Albany, N. Y. A very interesting bead made of rock-crystal, fluted and drilled from both ends, is in the collection of A. E. Douglas, in New York City. It is evidently native work, as it is improbable that foreign traders would use white rock-crystal beads, when glass would answer the purpose as well.

The Indians who lived in North Carolina previous to the advent of the white man occasionally noticed quartz crystals, as is shown by some being found in the mounds. They also realized the beautiful cutting edge that this material would possess if it were chipped in the form of an arrow point; and so they used up great quantities of the white quartzite for this purpose, and occasionally a transparent piece of quartz, either white or smoky. Many such objects,—of the chase or of war,—made of this beautiful material have been found, and are to be seen in our museums. Within the past 10 years, however, the demand for these transparent arrow-heads has increased, until the demand has so much exceeded the supply that some of the inhabitants, especially in Mitchell County, with remarkable cupidity and cleverness, have chipped arrow-points out of quartz crystals. These are in many ways quite as beautiful as the Indian work, but have no archæological value, of course, though they are to some extent sold as articles of ornament.

The highly modified crystals from White Plains, in Surrey County, and Stony Point, Alexander County, and also from Catawba and Burke counties, N. C., are worthy of note as being crystallographically unequalled anywhere, and as having formed the subject of special memoirs by Dr. Gerhard von Rath<sup>2</sup> (Pls. VI, A and VIII, A). A beautiful opalescent quartz has been found in Stokes County.

*Amethyst (Purple Variety of Quartz.)*—An almost unique gem in the collection of the United States National Museum at Washington is a piece of amethyst found at Webster, N. C., and deposited by Dr. H. S. Lucas. The present form is just such as would be made by a lapidary in roughly shaping a stone, preliminary to cutting and polishing it. It was turtle-shaped when found, though the shape was unfortunately destroyed by chipping, and was said to have borne marks of the handiwork of prehistoric man. It now measures  $3\frac{3}{8}$  inches (6 centimeters) in width,  $1\frac{1}{2}$  inches (4 centimeters) in thickness, and weighs  $4\frac{3}{4}$  ounces (135.5 grams). It is perfectly transparent, slightly smoky, and pale at one end, and also has a smoky streak in the center.

<sup>2</sup> Naturw. Verein, Westphalia, 1888.



In Haywood County a number of crystals of amethyst have been secured, some of which were cut into very fine gems.

In 1894 Mr. T. K. Brunner, of Raleigh, reported a yield of amethysts from Catawba, Macon, Wake, Lincoln, and other counties in the State; and in 1898 he stated that large amethysts of good color were still found in Lincoln County, together with smoky and lighter colored varieties.

In 1901 there was a decidedly promising effort to prosecute mining for amethysts on a commercial scale at Tessentee, on the creek of that name, in Smith Bridge Township, Macon County. Here a large vein of crystalline quartz occurs in an altered pegmatite. The development during the year was entirely in a kaolinized rock, in which the amethyst crystals, ranging from  $\frac{1}{2}$  inch to 3 inches in length, were found loose with the quartz and mica in the kaolin. The entire vein was exposed to the depth of 20 feet by a landslide. It would appear that further working should disclose the amethysts in the rock. The crystals are light and dark in color, and the dark spots are often of the deepest purple. No finer amethysts have been discovered in this country, and several thousand dollars worth of crystals were sold as the proceeds of the first development work.

Amethyst crystals, often of great beauty and of much crystallographic interest, have been found in various parts of the State, sometimes in remarkable quartz groupings, such as the so-called capped crystals, with purple tops raised upon slender stilt-like white crystals; others with rare faces, and then again enclosing water, especially from Lincoln County (see Pls. V, VI, B, and VII, B).

*Smoky Quartz.*—At Taylorsville and Stony Point, North Carolina, a number of clear pieces of this material have been found that cut fair stones weighing over an ounce each. In Alexander, Burke, Catawba, and adjacent counties, smoky quartz crystals which would afford fine gems are frequently met with. They are generally from 1 to 5 inches in diameter, sometimes of a citron or light yellow color, and often in groups weighing up to 100 pounds and over, quaintly grouped and often very clear. Crystals weighing as much as 40 pounds have been taken from the vicinity of Elkin, in Surrey County. Smoky and citrine quartz abound also in Iredell and Mitchell Counties.

At Stony Point, near Hiddenite post-office, Alexander County, N. C. have been found from time to time in the gneissoid rocks, pockets of quartz crystals varying from absolute pellucid and transparent to a dark smoky color. These are of wonderful brilliancy and purity, and range from  $\frac{1}{2}$  inch in length to a large size; but they are particularly remarkable from the fact that the faces of the crystals are highly and peculiarly developed.



SMOKY QUARTZ CRYSTALS, 7/16 NATURAL SIZE, HIDDENITE P. O., ALEXANDER COUNTY, N. C.



A QUARTZ CRYSTALS WITH AMETHYST TIPS NATURAL SIZE LINCOLN COUNTY N. C.



sometimes with great complexity (Pl. VI, A). They have furnished the subject for several monographs on the crystallography of quartz, notably those by Dr. Gerhard von Rath, of Bonn, and by Dr. Gill, of Cornell University. Some of the large complex groups are very interesting from their remarkable twinning-masses from 150 to 200 pounds, being made up of many crystalline faces, while in general contour a single large crystal. They stand quite unique as examples of beautiful color and marvelous crystallization (see Pls. V and VI, A).

The remarkable smoky crystals with included cavities, from Alexander County, are referred to further on, under quartz inclusions.

*Rose Quartz*.—Specimens of rose quartz from Dan River, Stokes County, N. C., show a beautiful opalescence, and the existence of like quartz, as well as asteriated quartz, in two other counties, Iredell and Cabarrus, was determined in 1894.

*Quartz Inclusions (sagenite)*.—North Carolina has yielded more of this material for gem purposes than all other American localities together.

Rutilated quartz of unexcelled beauty, the rutile brown, red, golden or black, has been brought to light in many places in Randolph, Catawba, Burke, Iredell, Jackson, and Alexander counties, especially the last, where in 1888 crystals of quartz, 3 inches in length, and filled with rutile the thickness of a pin, were secured at Stony Point (Pl. V). Beautiful series of these formerly in the collection of J. W. Wilcox, of Philadelphia, are now in the Morgan-Bement collection in New York. In 1901, fine rutilated quartz, well crystallized and perfectly transparent, was developed, together with handsome garnets, in the monazite mines near Shelby, Cleveland County.

Hornblende in quartz is reported as found in Burke, Alexander, and Iredell counties.

Mining operations at Stony Point, N. C., have brought to light a number of crystals 4 by 3 inches, and masses of quartz 6 by 3 inches, some of the former filled with what appears to be asbestos or byssolite, forming an interesting and attractive material susceptible of being cut into charms and other objects. Magnificent polished specimens are in the Morgan-Tiffany and Morgan-Bement collections. The inclosures of what is seemingly göthite in minute red, fan-shaped crystalline groups or tufts, form also a beautiful and interesting gem stone.

Among other inclusions, some of which might be utilized for gems, the following may be mentioned from North Carolina: Quartz, including scales of hematite from King's Mills, Iredell County; quartz containing crystals of green spodumene (hiddenite) from Stony Point; inclusions of

muscovite mica, that are green when viewed through the side of the prism, and of green chlorite, from several other localities in Alexander County.

A remarkable specimen of this kind, that was a "nine-days wonder" some years ago, was the so-called Gibsonville emerald. This was a stone weighing 9 ounces, plowed up near Gibsonville, Guilford County, which was pronounced a genuine emerald by some local expert, who tested it, and with the microscope showed that it contained various small diamonds. Its value was estimated up in the thousands, and \$1000 was reported to have been refused for it by its owner, who, as it was believed to be the largest known emerald, expected that it would bring him a fortune. Being, therefore, too valuable to be entrusted to an express company, he put himself to the expense of a trip to New York, where his prize proved on examination to be a greenish quartz crystal, filled with long hair like crystals of green byssolite or actinolite, on which were series and strings of small liquid-cavities that, glistening in the sun, had led to the included diamond theory. The best offer that he received for the stone was \$5.

*Fluid Inclusions.*—In March, 1882, Mr. William E. Hidden described and illustrated before the New York Academy of Sciences some unparalleled specimens obtained at Stony Point, Alexander County—the emerald locality elsewhere noted.\* Here some 400 pounds of choice large crystals of smoky quartz were taken out of a "pocket" in a quartz vein, besides much of less fine quality. These crystals were filled with cavities containing a clear lustrous fluid, and of extraordinary size, those of an inch long being not uncommon, and some of double that length. The largest was  $2\frac{1}{2}$  inches by  $\frac{1}{4}$  of an inch. So abundant were they that at times the crystals seemed to be made up of thin walls of quartz, separating a multitude of elongated cavities, parallel to the rhombohedral or prismatic faces of the crystals (Pl. VIII, B).

It is a matter of great regret that such unique specimens could not have been studied with the minute care given by Professors Dana and Penfield to those of Branchville, Conn. But now comes the singular conclusion of this account. The whole body of these crystals, carefully taken out and put aside as great treasures, were shattered into fragments in a single night, by the temperature falling below the freezing point. The contained fluid was evidently, as in the Branchville quartz, principally water, and its expansion in freezing destroyed the entire body of specimens. Those with few cavities exploded with sharp reports, and pieces were blown as much as 15 feet away. Those filled with small cavities were

\* On a Phenomenal Pocket of Quartz Crystals; Trans. N. Y. Acad. Sci., March, 1882.



A. GROUP OF QUARTZ CRYSTALS, PARALLEL CRYSTALLIZATION,  $\frac{5}{8}$  NATURAL SIZE, LINCOLN CO., N. C.



B. GROUP OF QUARTZ CRYSTALS, ENCLOSING CLAY AND WATER,  $\frac{5}{8}$  NATURAL SIZE, BURKE COUNTY, N. C.



reduced to little heaps of fragments frozen together in a coherent mass. All that remained for the illustration of Mr. Hidden's paper before the Academy, were flakes of flat pieces, parallel to the faces of the rhombohedron, and filled and clouded with elongated and often rod-shaped cavities, in great numbers and of conspicuous size.

So-called quartz pseudomorphs after calcite cleavages occur at a locality 2 or 3 miles northeast from Rutherfordton, Rutherford County, and frequently contain irregularly shaped cavities filled with water, which, if broken out in good shape, could be utilized as curious ornaments. This variety of quartz was also found by J. A. D. Stephenson in Iredell County. This occurrence was named and described by Mr. William E. Hidden of New York, and shown to be due simply to quartz filling irregular cavities between the mica crystals in a pegmatite rock. It is known as "box quartz."

#### NON-CRYSTALLINE QUARTZ.

As was stated above, these varieties have not been very prominent in North Carolina.

*Chalcedony*.—A rich fawn and salmon colored chalcedony has been obtained near Linville, in Burke County, and fine agates and chalcedony at Caldwell's, Mecklenburg County, near Harrisburg and Concord, Cabarrus County, and in Granville and Orange counties, and at some other localities in the State. A fine green-colored variety intermixed with black hornblende, that would afford gems an inch across, was found some years ago in Macon County, and moss agate near Hillsborough, in Orange County.

*Chrysoprase*.—This valuable variety of chalcedony, colored green by oxide of nickel, has recently been found in Buncombe County, near Morgan Hill, about 16 miles from Asheville.\* It appears in several parallel seams or veins, having a general N.E.-S.W. course, and within a few feet of each other. At the surface, the color was pale green, but as the rock was opened down to some 4 feet, the tint became deeper and richer. Only a little test work has yet been done, and the extent and commercial value of the material cannot at present be determined. The stone polishes very well, and if darker in color the deposit would have considerable value.

*Jasper*.—In North Carolina fine jasper, banded red and black, is found in Granville and Person counties; bright brick-red and yellow at Knapp's, Reed's Creek, Madison County; at Warm Springs; at Shut-in-Creek in

\*Min. Res. U. S., 1902, p. 57 (U. S. G. S. report).



developer of the first emerald mine in this country, William E. Hidden,<sup>1</sup> in 1881, and we cannot do better than quote his words. He writes:

Sixteen years ago, the site of the mine now being worked was covered with a dense primitive forest. Less than 10 years ago (1871), this country was mineralogically a blank; nothing was known to exist here having any special value or interest. Whatever we know of it to-day is due directly or indirectly to the earnest field work done here in the past 7 years by J. A. D. Stephenson, a native of the county, now a well-to-do and respected merchant of Statesville, N. C. Under a promise of reward for success, he engaged the farmers for miles around to search carefully over the soil for minerals, Indian relics, etc., and for several years he enjoyed surprising success in thus gathering specimens. The amount and the variety of the material gathered in this way was simply astonishing, and his sanguine expectations were more than realized. To be brief . . . I will state that from a few localities in the county Mr. Stephenson would occasionally procure crystals of beryl of the ordinary kind, but now and then a semi-transparent prism of beryl, having a decided grass-green tint would be brought to him. These the farmers named "green rocks" or "bolts," and became the principal object of the people's searchings. Mr. Stephenson had told them that a dark green beryl would be valuable if clear and perfect, would in fact be the emerald and for them to search more carefully than ever to find one. Surely, he had informed the people aright and had given them a *rara avis* to look for. It is sufficient to say that within a period of about 6 years there was found on 3 plantations in this county, loose in the soil, a number, say 10, of veritable emeralds, none of which, however, were dark-colored or transparent enough for use as gems. All of these specimens went into Mr. Stephenson's collection, with the single exception of one very choice crystal obtained at that locality by the late John T. Humphreys, which crystal is now in the New York State Museum at Albany, after first being in the collection of the late Dr. Eddy, of Providence.

The following historical account is from unpublished notes on North Carolina gems, prepared for the author by Mr. Stephenson himself in 1888:

The first beryl I collected suitable for cutting, was found early in 1875, at the locality now known as the Emerald and Hiddenite mine. It was a beautiful aquamarine, but only partly suitable for cutting. A few weeks later, I obtained at this locality my first emerald; it was small and rather opaque, but of fine color, and the file-like markings on its planes were very distinct. During 1876, I collected two others at the same locality. . . . During 1877, Mr. I. W. Miller brought me 2 emeralds found on his mother's farm, 2 miles northeast of the Emerald and Hiddenite mine. They were of good color and quite transparent, but very rough on the surface. This promising locality is still undeveloped.

<sup>1</sup> The Discovery of Emeralds in North Carolina, by W. E. Hidden. Privately printed, 8vo., 4 p., 1881, and also Trans. N. Y. Acad. Sci., 1882, pp. 101-105.

## CHAPTER VI.

### BERYL GEMS AND SPODUMENE (HIDDENITE).

#### BERYL (EMERALD, AQUAMARINE, GOLDEN BERYL).

This gem, chemically a silicate of alumina and glucina (or beryllia) and ranking among the most valuable of precious stones, is found quite extensively in North Carolina. Its commoner variety, beryl, occurs at many places in the State, and sometimes of beautiful gem quality; these are the aquamarines, blue to light green and the yellow or golden beryl. We will first treat of the precious variety, emerald.

*Emerald Beryl.*—Very few genuine emeralds have been found in the United States; and a number of reported specimens, assumed to be such, have proved upon examination to be only deep green beryls. The true emerald owes its color to a minute amount of oxide of chromium. Some beryls are of a very rich light green, and closely resemble emerald, so that they may easily be regarded as such; but they lack the depth of color so valued in the real emerald (see Pls. III and IX). The chief localities are Alexander and Mitchell counties, N. C., where emeralds, or beryls suggesting them occur. In the former it has been found at several different points, with quartz, rutile (some of the finest known), dolomite, muscovite, garnet, apatite, pyrite, etc., all in fine crystals. One of these places, Stony Point, is about 35 miles southeast of the Blue Ridge, and 16 miles northeast of Statesville, N. C. The surface of the country is rolling, the altitude being about 1000 feet above sea level. The soil, which is not very productive, is generally a red, gravelly clay, resulting from the decomposition of the gneissoid rock, and under these circumstances it is easy to find the sources of minerals discovered on the surface. Prof. Washington C. Kerr's theory of the "frost-drift" is well illustrated by the conditions that prevail throughout this region. The unaltered rock appears at Stony Point at a depth of 26 feet and is unusually hard, especially the walls of the gem-bearing pockets.

An exceptionally clear and reliable account of the search for minerals in Alexander County which resulted in the final uncovering of the important emerald and beryl deposits of Stony Point, has been given by the

developer of the first emerald mine in this country, William E. Hidden,<sup>1</sup> in 1881, and we cannot do better than quote his words. He writes:

Sixteen years ago, the site of the mine now being worked was covered with a dense primitive forest. Less than 10 years ago (1871), this country was mineralogically a blank; nothing was known to exist here having any special value or interest. Whatever we know of it to-day is due directly or indirectly to the earnest field work done here in the past 7 years by J. A. D. Stephenson, a native of the county, now a well-to-do and respected merchant of Statesville, N. C. Under a promise of reward for success, he engaged the farmers for miles around to search carefully over the soil for minerals, Indian relics, etc., and for several years he enjoyed surprising success in thus gathering specimens. The amount and the variety of the material gathered in this way was simply astonishing, and his sanguine expectations were more than realized. To be brief . . . I will state that from a few localities in the county Mr. Stephenson would occasionally procure crystals of beryl of the ordinary kind, but now and then a semi-transparent prism of beryl, having a decided grass-green tint would be brought to him. These the farmers named "green rocks" or "bolts," and became the principal object of the people's searchings. Mr. Stephenson had told them that a dark green beryl would be valuable if clear and perfect, would in fact be the emerald and for them to search more carefully than ever to find one. Surely, he had informed the people aright and had given them a *rara avis* to look for. It is sufficient to say that within a period of about 6 years there was found on 3 plantations in this county, loose in the soil, a number, say 10, of veritable emeralds, none of which, however, were dark-colored or transparent enough for use as gems. All of these specimens went into Mr. Stephenson's collection, with the single exception of one very choice crystal obtained at that locality by the late John T. Humphreys, which crystal is now in the New York State Museum at Albany, after first being in the collection of the late Dr. Eddy, of Providence.

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1. BERYL (EMERALD), ALEXANDER COUNTY, N. C.
2. BERYL (EMERALD), STONY POINT, N. C.
3. BERYL, ALEXANDER COUNTY, N. C.
4. BERYL (EMERALD) WITH RUTILE, ALEXANDER COUNTY, N. C.
5. BERYL CRYSTALS, GROUP.
6. BERYL (EMERALD) ON QUARTZ, STONY POINT, N. C.

the search for gems irregularly, for periods varying in length, for several years. Since 1885, however, but little has been done, owing to some legal disputes as to the property.

The largest emerald crystal found during this mining work was  $8\frac{1}{2}$  inches in length and weighed nearly 9 ounces (Pl. III, p. 8). It is now in the Morgan-Bement collection at New York. This was one of nine crystals contained in a single pocket, all excellent in color and partially transparent, but somewhat flawed. One was 5 inches in length and others were over 3 inches (Pl. III).

One of the most noteworthy gems cut from the product of this mine was from a crystal found in a pocket at a depth of over 43 feet. Its color is a pleasing light green and it weighs  $4\frac{23}{32}$  carats. In 1887, at a depth of about 70 feet, another crystal was obtained that yielded a cut stone of 5 carats. Both of these are too light in color to rank as fine gems. The two largest, and a series of the smaller ones, went into the cabinet of Clarence S. Bement, now the Bement-Morgan collection in the American Museum of Natural History. Some fine ones are also in the British Museum. The rich emerald color in many of these crystals is confined to a border from  $\frac{2}{100}$  to  $\frac{3}{100}$  of an inch in thickness around the edge and near the termination of the crystals. If this edge were thicker, fine gems could be cut from it.

The value of the emeralds in this deposit was relatively small compared with that of the many slender crystals of hiddenite. Both these species are in part silicates of alumina, but they differ in the other basic element present, which, in hiddenite, is lithia, while in the emerald it is glucina. Both gem stones owe their color to the same substance, oxid of chromium. The emeralds found in this mine were very rarely without flaws, while the hiddenite was notably free from such defects, and varied in shade from a yellowish green to the deepest blue-green, often odd combining both extremes of color in the same crystal.

The chemical composition of the emerald beryl is shown in the analysis given below of a leek-green colored beryl from Alexander County:

*Analysis of Emerald Beryl.*<sup>1</sup>

Specific Gravity, 2.703.

Con-stituent.	Per cent.
Silica .....	66.28
Alumina .....	18.60
Ferrous oxide .....	0.22
Beryllia .....	13.61
Water .....	0.83
Total .....	99.54

<sup>1</sup> F. A. Genth, Analyst.

In the soil overlying the rock and resulting from its decomposition, nine crystals of emeralds were found, later, all doubly terminated and measuring from 1 to 3 inches (25 to 77 millimeters) in width. The latter crystal is very perfect as a specimen; it is of fine light green color and weighs  $8\frac{3}{4}$  ounces, or only  $\frac{1}{4}$  ounce less than the famous Duke of Devonshire emerald crystal (Pl. III). Another crystal measuring  $2\frac{1}{2}$  inches (63 millimeters) by  $1\frac{1}{12}$  inch (25 millimeters) is filled with large rhombohedral cavities, formerly containing dolomite. As mineral specimens these are quite unique.

Some peculiar features pertaining to the emeralds and beryls from this region, are particularly noted by Mr. Hidden.\* "They appear," he says, "as though filed across the prismatic faces." The basal plane is also often pitted with minute depressed hexagonal pyramids, that lie with their edges parallel to one another, and to the edge of the di-hexagonal prism. Rarely, though, crystals are found with perfectly smooth and brilliant faces. The emerald color is often focused on the surface and fades gradually to a colorless central core, which feature is of exceeding interest when the genesis of the mineral is considered.\* A similar etching or corrosion appears in beryls from Colorado and those from Pala, California. A remarkable fact is that we have here a green beryl (emerald) and emerald green spodumene (hiddenite), and in the Pala, California, mine, we have lilac spodumene (kunzite) and pink beryls.

Some beryls and emeralds of pale color were also collected by Mr. J. A. D. Stephenson, 1 mile southwest of the Stony Point deposit and a short distance from the place where the same mineral was found by Mr. Smeaton, of New York. Such discoveries tend to show that the deposit is evidently not the only one, and that there is still encouragement for future working in this region.

In July, 1894,<sup>4</sup> a new locality of true emeralds, in the western part of the State, was discovered by Mr. J. L. Rorison, a pioneer miner of mica, and Mr. D. A. Bowman, on the Rorison property, 14 miles from Bakersville, and about the same distance from Mitchell's Peak, Mitchell County. Here, at an elevation of 5000 feet, on Big Crabtree Mountain occurs a vein of pegmatite some 5 feet wide, with well defined walls, in mica-schist. It outcrops for perhaps 100 yards, with a north-and-south strike (Pl. X).

This vein carries a variety of minerals besides its component quartz and feldspar, among these being garnets of a translucent reddish color, and black tourmaline, the latter abundant in slender crystals; beryls, white,

\*Am. Jour. Sci., III, Vol. XXXIII, p. 505, June, 1887.

<sup>3</sup>See Rep. Dept. Mining Statistics. George F. Kunz, 1903.

<sup>4</sup>16th Ann. Rep. U. S. Geol. Sur., Part IV, p. 600, 1894.

yellow, and pale green; and the emeralds. These last are chiefly small, 1 to 10 mm. wide by 5 to 25 mm. long, but some have been found two or three times the size of the largest above-named. They are perfect hexagonal prisms, generally well terminated with basal planes, and are of good color, with some promise for gems. They very strikingly resemble the Norwegian emerald from Arendal.

It will be noticed that the occurrence here is entirely different from that in Alexander County, being not in veins of quartz, but in a pegmatite dike. The latter is the usual situation in which beryls are found, from New England to the Carolinas, and also the large deposits of mica suitable for mining. This emerald locality has been lately worked by a New York company, and, although but few perfectly transparent gems have yet been obtained, a beautiful ornamental stone has been developed. The crystals vary from  $\frac{1}{8}$  of an inch to  $1\frac{1}{4}$  inches in diameter, and are rarely over 1 inch in length. Though not clear, they have rather a fine emerald color, and penetrate the quartz and feldspar in an irregular manner. This green and white mixture is very pleasing; and as the feldspar has a hardness of 6.5, the quartz of 7, and the emerald of about 8, the whole can be cut and polished together. Pieces are cut *en cabochon*, showing sections of one or more emerald crystals on the top and sides of the polished stone. The name of "emerald matrix" is given to this ornamental gem material (see illustration in Morgan-Tiffany collection) (see Pl. III). This property, which was worked quite extensively in 1906 by the American Gem and Pearl Company, of New York, produced some perfectly transparent crystals of emerald which cut good gems up to  $\frac{3}{4}$  carat in weight.

Far to the southwest of Stony Point and some 50 miles south of the emerald locality near Bakersville, a second new occurrence was noted in 1897 by Mr. J. Meyer of Charlotte, N. C., who had found near Earle Station, in that State, between Blacksburg, S. C., and Shelby, N. C., a broken fragment of emerald of good color, better than anything observed from North Carolina, although somewhat flawed; it was cut into a facet stone, of trapeziform, or sub-triangular shape, weighing  $4\frac{15}{16}$  carats that quite closely resembles the material from the Muzo mine of Colombia.

*Aquamarine, Yellow and Golden Beryl.*—This mineral, as above stated, is found at many localities in North Carolina, and sometimes of quite fine enough to yield choice gems. It will be noted that beryl localities are met with on both sides of the Blue Ridge, both in the Piedmont region and west of the mountains. Here again, for the development of and many other forms of mineral wealth in North Carolina, in the following the devastation of the Civil War, a lasting debt is due to Mr. J. Adlai D. Stephenson, of Statesville, and also to the late



EMERALD MINE, CRABTREE MOUNTAIN, MITCHELL COUNTY, N. C., ABOUT 25 MILES FROM MARION.





Thomas L. Clingman, who after serving as a brave officer in the Southern army, turned his energies to the cultivation of the arts of peace and the improvement of the natural resources of his State (see Pls. III, IX, and XI).

Mr. Stephenson published accounts from time to time of his researches and discoveries, beginning soon after the war, and continuing for a number of years. A number of beryl localities are noted by Mr. Stephenson in the counties of Alexander, Burke, Caldwell, Cleveland, Macon, Mitchell, and Yancey, some of them yielding choice material (Pl. IX). The remarkable discovery of emerald beryls at Stony Point, Alexander County, has been already described under emerald; but there are numerous occurrences of beryl in the State, closely resembling those of New England, both in size and variety. Mr. Stephenson called the attention of the author to a dark green beryl, weighing 25.4 ounces, part of which would furnish gems of some size, that was found in January, 1888, near Russell Gap Road, Alexander County, by a farmer plowing. This locality, about 10 miles from Stony Point, is the largest beryl deposit affording gems that has been opened in North Carolina. It is noteworthy that the highly modified beryls of this region occur rarely, and only when associated with spodumene or albite, and also that the white or pale greenish beryls are found with the deepest green spodumene. It has before been noted that the quartz and beryl of Alexander County are more highly modified when implanted on the feldspathic layers of the walls of the pockets. We have here a green spodumene and a green beryl (emerald); we have the same minerals, rose or lilac colored (kunzite) and rose beryl, at Pala, California. Two emerald beryls found in 1881, at a depth of 34 feet, were in a little cavity, the walls of which were almost covered with crystals of albite twinned parallel to the base. Only four emeralds were found, averaging about 1 cm. in the three dimensions. The pocket was free from all decomposition whatever. The crystals were of good color, transparent, and had their commoner planes well polished, but they differed to some extent in habit.

Some of the North Carolina beryls, especially the fibrous, green, opaque beryl from Alexander County, would furnish cat's-eyes, although not very fine.

A rich yellow crystal was reported in 1888 by Mr. Stephenson, as found in a quartz boulder, with finely crystallized tourmaline, near Little River Church, Alexander County. Beryl, resembling the Siberian, occurs in greenish-yellow and deep green crystals, in the South Mountains, 9 miles southwest of Morganton, Burke County; also in the Sugar Mountains at Shoup's Ford, Dietz's, Huffman's, and Hildebrand's. A rich

blue-green crystal in quartz was found at Mill's gold mine, Burke County, and a fine transparent green crystal from that vicinity is now in the cabinet of M. T. Lynde, of Brooklyn, N. Y. Another Piedmont locality is at Wells, in Gaston County.

Some of the beryls from the neighborhood of Statesville are of unusual interest from their crystalline forms; these have been described and in part figured by Mr. W. E. Hidden.\*

Passing to the counties west of the Blue Ridge, several good localities are known where fine beryls occur, generally in pegmatite dikes, like the Bakersville emeralds. Clear green beryls have also been obtained at Balsam Gap, Buncombe County; Carter's mine, Madison County; Thorn Mountain, Macon County, and at one or two points in Jackson County. The following, however, are more important:

Blue beryl in fine crystals that afforded fair gems was found near the Yancey County line, and golden beryl in the same vicinity, as noted by Dr. Pratt. Some crystals 2 feet long and 7 inches in diameter, with small clear spots, which would cut into gems, occur 4 miles south of Bakersville, and near Grassy Creek, both in Mitchell County (Pl. III). Fine blue-green aquamarine is known at Ray's mica mine on Hurricane Mt., Yancey County.

The Grassy Creek locality, just noticed, has attracted some attention recently as a source of fine aquamarine. It is situated on Brush Creek Mountain, Estatoe P. O.,<sup>5</sup> Mitchell County. The beryls occur in a pegmatite dike that cuts across the country rock (gneiss) at a low angle, instead of conforming to the steep lamination of the latter, as do the ordinary mica veins. These last are chiefly muscovite, while the dike consists of quartz and albite, with black mica (biotite), garnet, black tourmaline, titanite iron and beryls. Most of the latter are opaque and yellowish, the bright green ones being only occasionally found, and not always in the dike, but sometimes in the adjacent mica-schist,—as though a product of contact alteration. The best crystals have a fine aquamarine tint, and some have yielded very perfect gems of more than a carat in weight. Some honey-yellow beryls also occur, sufficiently clear for cutting, but these are rare.

Another locality in Mitchell County, very promising as a source of aquamarines, is the Wiseman mine at Flatrock, near Spruce Pine P. O. Here the beryls occur not in a dike, as in the last instance, but in connection with veins of muscovite mica that run with the gneiss rock.

\* Am. Jour. Sci., Vol. XXII, August, 1881.

<sup>5</sup> J. H. Pratt. Jour. Elisha Mitchell Sci. Society, Vol. XIV, Part 2, 1897, p. 80.



BERYL CRYSTALS, GROUP, NATURAL SIZE, BURNSVILLE, N. C.



Several colors are found here; some are of fine aquamarine tint, and have yielded very perfect gems of more than a carat; less frequently they are honey-yellow, with portions clear enough to be cut; while rich blue ones, equal to any of those from Brazil, have also been obtained in the course of the past 15 years, first by desultory working and then by the most systematic operations under the American Gem Company, of New York City. Large quantities,—thousands even,—of magnificent blue gems weighing from 1 to 20 carats, have been taken out here. (See Pl. II.)

At the Littlefield mine, on Tessentee Creek, Macon County, clear aquamarines have been obtained which have cut into beautiful gems.

At the Charleston Exposition of 1901,<sup>1</sup> Dr. J. H. Pratt exhibited, among other choice minerals of North Carolina, a crystal of golden beryl  $1\frac{1}{2}$  inches in diameter and  $2\frac{1}{4}$  inches long, obtained from an Indian mound near Tessentee Creek, not far from the Littlefield mine, and hence presumably from that locality. This is the first instance recorded of a beryl crystal found deposited in an Indian grave.

Another important locality in Macon County is the McGee mine. Here the gems are sea-green and occasionally yellow, and are found in quantity.

A fine representation of the North Carolina beryl is to be seen in the museum of the State University at Chapel Hill, together with the other minerals of the State, collected by the late Mr. Stephenson, in the course of his enthusiastic explorations, and whose cabinet was most appropriately secured by the State.

#### HIDDENITE OR LITHIA EMERALD.

This is a stone which is peculiar to North Carolina, and hence possesses especial interest in any account of the minerals of that State. The circumstances under which it first came into notice have already been mentioned under Emerald, with which it was found, at Stony Point, Alexander County, in about 1879. Mineralogically, it is a variety of spodumene, a well-known silicate of alumina and lithia, usually found in large rather coarse crystals, opaque and of no beauty. Occasionally, however, it is transparent and richly colored (Pl. III). The first occurrence of this form of it in the United States, was in these small brilliant, green crystals in North Carolina; a second has lately attracted much attention in San Diego County, California, where the crystals are large and of a rose-lilac tint; this variety is the new gem-stone called kunzite.

The history of the North Carolina discovery is as follows:

About 1879, some crystals of a yellow and yellowish-green mineral,

<sup>1</sup> Report Dept. Mining, Charleston Exposition, 1901.

supposed to be diopside, were found at Stony Point, Alexander County, N. C., associated with beryl, quartz, rutile, garnet, dolomite, etc. These crystals soon came into the hands of J. A. D. Stephenson of Statesville, who sent the best of them to Norman Spang, of Pittsburg, Pa., a noted collector of choice minerals. About 2 years later Mr. Stephenson called the attention of William E. Hidden to this mineral, and to the locality; Mr. Hidden then sent specimens for examination to Dr. J. Lawrence Smith, of Louisville, Ky., who found, on investigation, that the mineral was not diopside but a transparent variety of spodumene. The crystals were first found loose in the soil with emeralds, but systematic mining revealed them attached to the veins of the wall-rock (Pl. XII, A). The spodumene is generally more or less altered, hence its pitted or eaten-out appearance; but when found in the rock, the crystals are quite perfect and unchanged. They are all transparent and range from colorless (rare), to a light yellow, into yellowish-green, then into deep yellow emerald-green. Sometimes an entire crystal has a uniform green color, but generally one end is yellow and the other green. Its hardness is on the prism faces, 6.5, and across them, according to Doctor Smith, nearly that of the emerald; but a series of experiments proved it to be somewhat less. At first considerable difficulty was experienced in cutting it, owing to its remarkably perfect prismatic cleavage, which is very lustrous. Gems have, however, been cut up to  $2\frac{1}{2}$  carats in weight. Specific gravity, 3.18 to 3.194.

Specimens of the crystals and of cut stones, have gone into all important public and private collections in the United States, and to some extent abroad. Dr. Spencer, of the British Museum, has recently described several specimens there contained, in a report to the Director, Dr. Fletcher, as follows:

**HIDDENITE:** Alexander County, N. C.

A faceted stone of a rich emerald-green color, perfectly transparent, and with only 1 or 2 small cracks. Weight, 0.494 gram.

A piece of matrix bearing 2 or 3 small crystals. Also numerous isolated prismatic crystals up to  $2\frac{1}{2}$  centimeters in length; many rather pale in color, but 3 crystals, presented by Mr. Hidden, in 1893, of a rich emerald-green.

The yellow tinge exhibited by this mineral in even the darkest green gems will prevent it from competing with the emerald, since it is this very quality that has kept down the prices of the Siberian demantoids, or Uralian emeralds, as the green garnets are variously termed. The finest crystal of lithia emerald ever found is in the Morgan-Bement collection at New York. (See Pl. III.) It measures  $2\frac{3}{4}$  inches (68

millimeters) by  $\frac{1}{2}$  inch (14 millimeters) by  $\frac{1}{4}$  inch (8 millimeters). One end is of very fine color, and would afford the largest gem yet cut from this mineral, weighing perhaps  $5\frac{1}{2}$  carats. In Dr. Augustus C. Hamlin's cabinet is a fine gem weighing about 2 carats; and a cut stone of fine color, and a good crystal are in the collection of Col. W. A. Roebling. Dr. J. Lawrence Smith<sup>\*</sup> says that the crystals, when cut and polished, resemble the emerald in luster though the color is not so intense as in the finer varieties of the latter gem. Prof. Edward S. Dana says that, owing to its dichroism, it has a peculiar brilliancy which is wanting in the true emerald. Thomas T. Bouvé, of Boston, says: "One might infer from the statement made of the great brilliancy of both the hiddenite and garnet, when compared with the emerald, that this should decide their relative beauty; but it is not the case, for the emerald has a beauty of its own, in its deep and rich shade of color, that will ever make it rank at least an equal in loveliness with the newer aspirants for favor." When the hiddenite was first introduced, it had a considerable sale because of its novelty as an American gem and because of the newspaper notoriety it gained through the controversy that arose as to its discovery. Hence for a time the demand exceeded the supply, which, from the desultory working of the mine, was limited. Thus a  $2\frac{1}{2}$  carat stone was sold for \$500.00, and a number of stones brought from \$40.00 to over \$100.00 a carat. The total sale of all the gems found, from the beginning of operations in August, 1880, to the close of 1888, amounted to about \$7500.00, the yield in 1882, during which the preparatory work was done, being about \$2000.00. At the time of the discovery, this was supposed to be the first occurrence of transparent spodumene; but Pisani, in the *Comptes Rendus* for 1877, announced a transparent yellow spodumene that had been found at Minas Geraes, Brazil, where it exists in large quantities and has been extensively sold as chrysoberyl. The writer saw nearly a ton of broken crystals of this mineral at Idar, Germany, in 1881, whither it had been sent for cutting. A stone from Brazil weighing 1 carat is in the United States National Museum, as also a series of crystals and cut stones from North Carolina. At Branchville, Conn., spodumene is found in opaque crystals 4 or 5 feet long and a foot in diameter, almost entirely altered to other minerals. In spots, however, it is transparent enough to furnish small gems of an amethystine color. The alterations which have taken place have entirely changed it to what might almost be called a defunct gem; otherwise, these crystals would have afforded gems

<sup>\*</sup>Am. Jour. Sci., III, Vol. XXI, p. 128, Feb., 1881.

<sup>\*</sup>Proc. Boston Soc. Nat. Hls., Vol. XXIII, p. 2, Jan. 2, 1884.



over an inch in thickness and several inches in length. The color before the alteration was probably much richer pink. It is of mineralogical value only.

Within the past year, the discoveries in San Diego County, California, have brought to light spodumene of a similar color with the little remnants at Branchville, but entirely clear and unaltered.

The North Carolina mineral was given its name by Dr. J. Lawrence Smith (who first determined its true character) in honor of Mr. W. E. Hidden. The crystals are slightly inclined prisms in form, ranging from quite small up to perhaps 2 inches in length and from  $\frac{1}{4}$  to  $\frac{1}{2}$  of an inch in diameter, for the largest. The first crystal of any size that was found, was shown in the remarkable North Carolina gem-exhibit at the Charleston Exposition of 1901-02. Notwithstanding the interest which attaches to this peculiar and beautiful American gem, no further developments of it have been made for several years, owing to the mines at Stony Point being closed under litigation.

The chemical composition of hiddenite is given in the following table of analyses:

*Analyses of Hiddenite.*

Specific Gravity, 3.152-3.189.

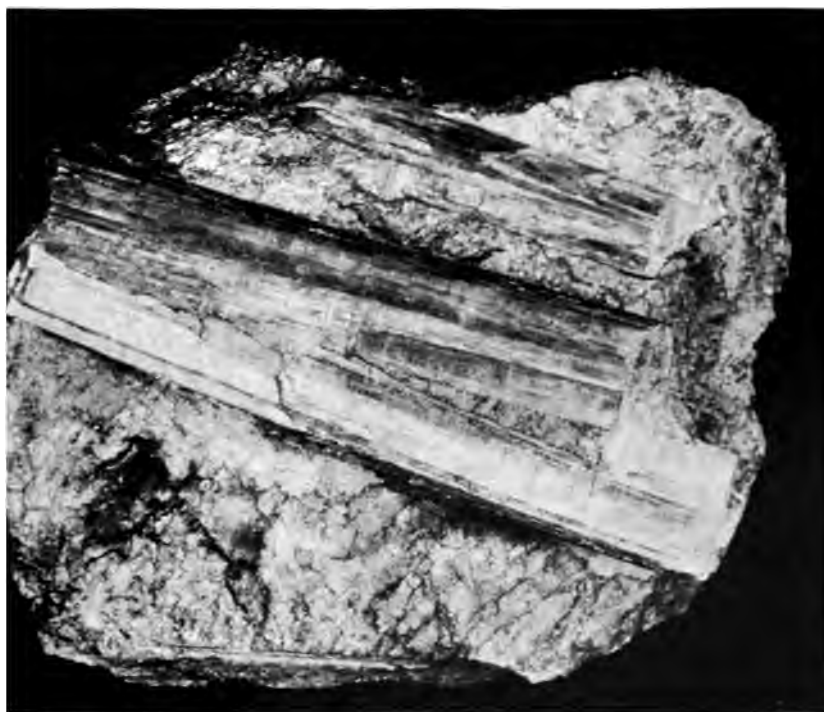
Constituent.	Per cent. <sup>1</sup>	Per cent. <sup>2</sup>
Silica .....	63.95	64.35
Alumina .....	26.58	28.10
Ferric Oxide .....	....	0.25
Chromic Oxide .....	0.18	....
Ferrous Oxide .....	1.11	....
Lithia .....	6.82	7.05
Soda .....	1.54	0.50
Potassa .....	0.07	....
Water .....	....	0.15

<sup>1</sup> F. A. Genth, analyst, Am. Jour. Sci., III, 23, 68.

<sup>2</sup> J. Lawrence Smith, analyst, Am. Jour. Sci., III, 21, 128.



A. SPODUMENE (HIDDENITE) IN MATRIX, NATURAL SIZE, STONY POINT, N. C.



B. CYANITE, NATURAL SIZE, BURNSVILLE, N. C.



## CHAPTER VII.

### GARNET, ZIRCON, RUTILE, AND OCTAHEDRITE.

#### GARNET.

The name garnet is applied not to any single mineral, but to a well-marked little group, comprising several species and varieties, differing in color and chemical composition, but very closely related physically. They all crystallize in the isometric system, and are all constructed on the same type chemically, though varying considerably in their components. They are silicates of lime, magnesium, iron, or manganese, with more or less of alumina, ferric iron or chromium. According to the presence and the proportions of these substances, the species and varieties are determined. Several members of the garnet group are found in North Carolina, some of the commoner kinds in large quantities, so that they have been mined for use as an abrasive and some of choicer quality that yield beautiful gems.

Of the latter are to be noted the following: Almandine or precious garnet, the iron-alumina variety; pyrope or Bohemian garnet, the magnesia-alumina variety; rhodolite, a peculiar and beautiful garnet intermediate between these two; and spessartite, or manganese-alumina garnet. This last is rare and the only North Carolina occurrence of it is reported by Dr. J. H. Pratt, in beautiful flattened plate-like crystals in mica, near Bakersville, some large enough to cut gems of a carat or more.<sup>1</sup> Very elegant crystals of large size have been found at Amelia Court House, Virginia, in an albite pegmatite. This variety is not red, but of a peculiar rich brown or fulvous tint (Pl. XIII).

*Almandite* is the most frequent variety, and the one that has been mined for garnet paper and other abrasive purposes, including a so-called "emery," for which tons of it have been crushed. The color is red, of many shades, varying to brownish and purplish reds. The peculiar play of color observed in some of the North Carolina garnets is usually due to inclusions. In Burke, Caldwell, and Catawba counties are found large dodecahedral and trapezohedral almandite crystals coated externally with a brown crust of limonite, the result of superficial alteration, but

<sup>1</sup>Gems and Precious Stones of North America, New York, 1890, pp. 79-83.

usually showing a bright and compact interior when broken. They are sometimes as fine in color as the Bohemian garnets, and should find a ready use for watch-jewels and other like purposes. Some crystals have been found weighing 20 pounds each. Although not fine enough for gems, these might be cut into dishes or cups measuring from 3 to 6 inches across, as has been done in India. A very large quantity of these garnets has been found about 8 miles southeast of Morganton, and also near Warlick, in Burke County. Here they have been extensively mined for abrasive use and also near Hall's Station in Jackson County, where garnet wheels are manufactured.

*Bohemian or pyrope garnets.*—This garnet of good color, that has furnished gems, has been found in the sands of the gold-washings of Burke, McDowell, and Alexander counties. This species has a more blood red tint than the preceding, and is used largely in the garnet jewelry made in Bohemia, whence the name; it is the same also that passes under the name of Cape ruby, from South Africa, and Arizona ruby, from the territory of that name.

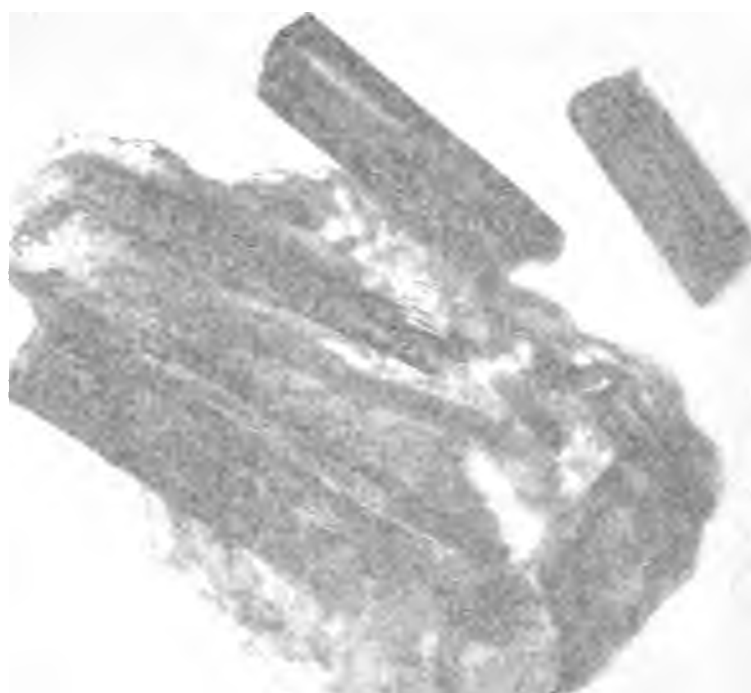
*Rhodolite.*—This is by far the most important variety of garnet in North Carolina, and is found nowhere else, indeed, so that it possesses peculiar interest. Since it has been recognized and developed, it has proved to be also the most valuable gem produced commercially in the State. The locality is much the same as that of the Cowee rubies, in Macon County, in the gravels of streams heading on Mason's Mountain, and on the mountain itself at some points. When first observed it was regarded as a very beautiful and brilliant light-colored form of almandine; but analysis subsequently showed that it is a variety intermediate between that and pyrope, in fact an inter-mixture of the two, in the proportion of  $\frac{2}{3}$  pyrope and  $\frac{1}{3}$  almandine.

The first mention of these Macon County garnets was apparently due to Mr. A. M. Field, of Asheville, in 1893,<sup>2</sup> and was made by the author in his report on the production of precious stones for that year, and again in 1897.<sup>3</sup> In the following year, a paper was published by Mr. W. E. Hidden and Dr. J. H. Pratt, in which the whole subject was treated fully, the analyses described, the nature of the stone determined, and the name of rhodolite proposed for it as a new variety.<sup>4</sup> This name is from the Greek word *rhodon*, a rose, from the resemblance of its color to some kind of roses and rhododendrons. The mineral shows a light shade of fine red, without the dark aspect that belongs to most garnets, and it

<sup>2</sup> Min. Res. U. S., 1893 (Rep. U. S. Geol. Survey), pp. 15 and 19.

<sup>3</sup> Min. Res. U. S., 1897 (Rep. U. S. Geol. Survey), p. 13.

<sup>4</sup> Am. Jour. Sci., IV, Vol. V, 1898, pp. 293-296; and also Vol. VI, pp. 462-468.







A  
Cyanite,  
Green Mountain Ridge, Mitchell Co.,  
North Carolina.



B  
Cyanite,  
Green Mountain Ridge, Mitchell Co.,  
North Carolina.



C  
Rhodolite,  
Chestnut Valley,  
Waynes Co., North Carolina.



D  
Rhodolite,  
Chestnut Valley,  
Waynes Co., North Carolina.





possesses a remarkable degree of brilliancy, especially in artificial light. Those qualities give it great value for gem purposes, and it has become very popular. The pieces found are not generally large, but stones have been cut of as much as 14 carats. A very fine exhibit of rhodolites was made in the State Geological Survey Exhibit at the recent Expositions at Buffalo, Charleston, and St. Louis. They have been developed by two companies with remarkable success; and apparently more gems in value have been sold from this mine than from all other sources in the State combined. (See Pl. XIII.)

Perhaps \$53,000 worth of these stones have been sold from these mines to date.

#### ZIRCON.

*Zircon* (silicate of zirconia) is a mineral of somewhat wide distribution, though rarely conspicuous. It crystallizes in square prisms with pyramidal terminations, generally opaque and of some shade of brown. When transparent, and of any size, beautiful gems can be cut from zircon crystals; these are the hyacinths of jewelers.

In North Carolina zircon is abundant in the gold sands of Polk, Burke, McDowell, Rutherford, and Caldwell counties, and in nearly all the colors found in Ceylon—yellowish-brown, brownish-white, amethystine, pink, and blue. The crystals are beautifully modified, but too minute to be of value. Brown and brownish-yellow crystals, very perfect in form, occur abundantly in Henderson County, N. C., and in equal abundance in Anderson County, S. C. The latter are readily distinguished from the North Carolina crystals, as they are generally larger, often an inch across, and the prism is almost always very small, the crystal frequently being made up of the two pyramids only. They are found in large quantities, loose in the soil, as the result of the decomposition of a feldspathic rock. Large and richly colored zircons, sometimes as much as 2 ounces in weight, and of fine shades of brown and honey-red, are found in Iredell County.\*

Within the past 20 years some demand has arisen and continued for minerals containing the rare earths,—zirconia, thoria, etc.,—as these substances are used for the mantles or hoods of the Welsbach and other forms of incandescent gas burners. This demand led to active search throughout the world for the minerals containing these oxides, and so successful has been this search that many species which were once considered rare are now so plentiful that they are quoted at one-tenth to one-

\* N. C. Geolog. Survey, Economic Paper, No. 6, 1901, p. 99; and Department of Mining Statistics, 1898, p. 34.

hundredth of their former prices. The best zircon localities in North Carolina are on the Old Meredith Freeman estate, and the Jones estate, Green River, Henderson County. It was leased for 25 years by Gen. Thomas L. Clingman, who, as early as 1869, mined 1000 pounds of zircon, and during that whole period never lost faith in the incandescent properties of zirconia; but when these were finally proved and acknowledged, through some legal difficulties General Clingman had forfeited his leases, and hence failed to reap his reward. The zircon industry has been quite important in North Carolina; and as far back as 1883 Mr. W. E. Hidden mined 26 tons in that single year. The chemical composition of zircon is shown below in the analysis of a sample of this mineral from Buncombe County.

*Analysis\* of Zircon from Buncombe County, N. C.*

Specific Gravity, 4.607.

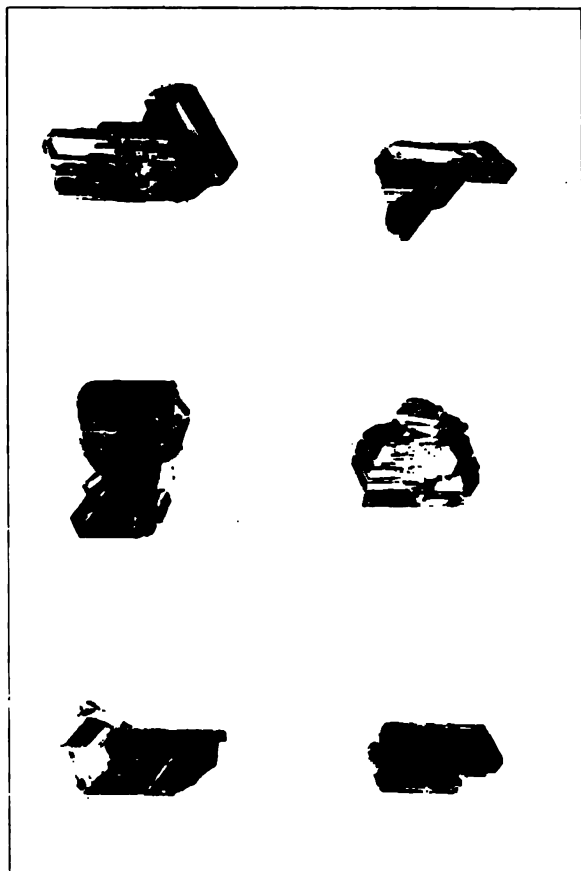
Constituent.	Per cent.	Theoretical per cent.
Silica .....	33.70	32.80
Zirconia .....	65.30	67.20
Ferric Oxide .....	0.67	.....
Water .....	0.41	.....

**RUTILE.**

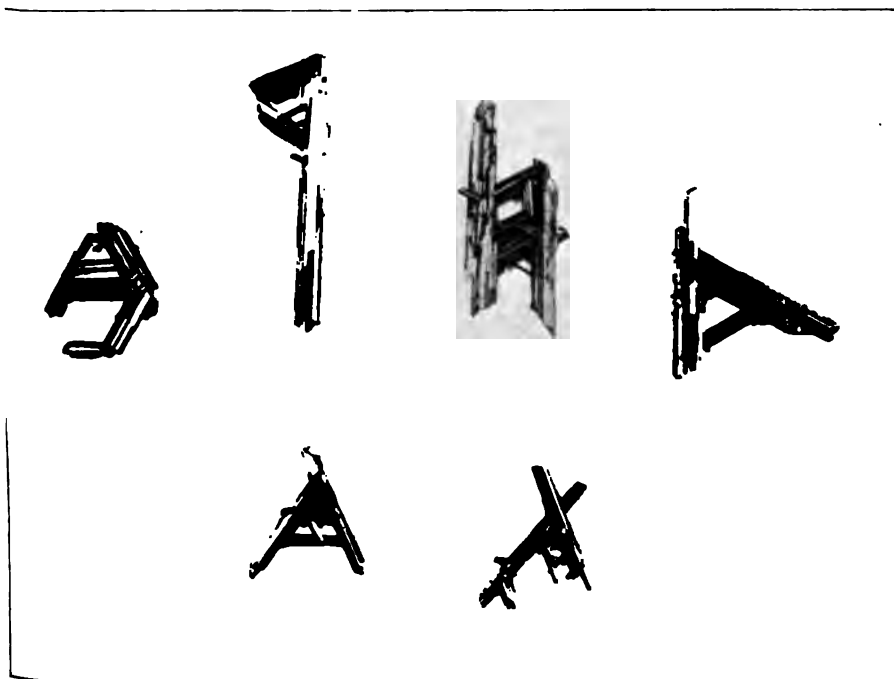
This is one of the most interesting minerals found in North Carolina, although not one that is very conspicuous. In composition, it is pure oxide of the metal titanium, and varies in color from deep red or reddish-brown to black, the crystals being modified square prisms. Specimens from Alexander County rival any that have ever been found for their perfection of form, wonderful polish, and fine color (Pl. XIV, A and B, and Pl. XV). At Graves Mountain, Georgia, elegant rutile occurs with lazulite usually imbedded in a compact red oxide of iron that can be readily removed by hydrochloric acid, or with a sharp instrument, leaving on the surfaces a mirror-like polish. The crystals vary in length from  $\frac{1}{2}$  an inch up to 5 inches, and are either single, twins, or vierlings, often in fine groups. The rutile from this locality has realized at least \$20,000 for cabinet specimens, and has supplied the collections of the world through the perseverance of Prof. Charles U. Shepard. It occurs in a similar association with lazulite in North Carolina, at Crowders Mountain, in Gaston County.

The finest small brilliant geniculated crystals are found at Millholland's Mills, White Plains, near Liberty Church, and near Poplar Springs, in

\* C. F. Chandler, analyst, Am. Jour. Sci., II, 24, 131.



A. RUTILE CRYSTALS, NATURAL SIZE, STONY POINT, N. C.



B. RUTILE, RETICULATED, NATURAL SIZE, NEAR HIDDENITE P. O., ALEXANDER COUNTY, N. C.



Alexander County, see Plate XIV. These have furnished some of the finest cut black rutile, which more closely approaches the black diamond in appearance than any other gem. Some of the lighter colored ones furnish gems strongly resembling common garnet. Beautiful long crystals at times transparent red, ranging from the thickness of a hair to  $\frac{1}{4}$  and in some instances  $\frac{3}{8}$  inch across, and from 1 inch to 6 inches in length, often doubly terminated and very brilliant, have been found at Taylorsville, Stony Point, and elsewhere in that vicinity. A very marked form of rutile is that in which these slender red crystals penetrate transparent quartz, both colorless and smoky, forming the beautiful combination called sagenite, or by the French, "flèches d'amour" (love's arrows) (Pl. V). This material is found of remarkably fine quality at several points in North Carolina, and is described in this report under Quartz Inclusions.

Dr. Joseph Hyde Pratt has recently reported the occurrence of beautifully terminated rutile crystals from near Mebane, Orange County. The crystals are up to  $1\frac{1}{4}$  inches long and  $\frac{1}{2}$  broad and are imbedded in pyrophyllite.

#### OCTAHEDRITE.

*Octahedrite* is a rare mineral, identical with rutile in composition, but entirely different in the form of its crystals. It is described by W. E. Hidden<sup>1</sup> as occurring in thin tabular, glassy crystals of a pale-green color and very brilliant up to  $\frac{1}{4}$  of an inch in diameter, in the gold sands of Brindletown Creek and elsewhere in Burke and the adjoining counties, especially on the northern slope of Pilot Mountain. These might afford small gems that would compare favorably with the beautiful blue crystals from Brazil, which are so brilliant as to have been mistaken for diamonds. Cassiterite, the oxide of tin, has been found in considerable quantities at King's Mountain. Fine specimens may be cut like rutile, but this place has not yielded a single gem, or been worked as yet with commercial success for tin.

<sup>1</sup> Am. Jour. Sci., III, Vol. XXII, July, 1881, p. 26.

## CHAPTER VIII.

### CYANITE, EPIDOTE, TOURMALINE, CHRYSOLITE (PERIDOT), SERPENTINE, SMARAGDITE, LAZULITE, MALACHITE, AND PEARLS.

#### CYANITE.

This mineral (also spelled kyanite) is a subsilicate of alumina almost identical in composition with andalusite, and very closely related also to topaz. It is named from the Greek *kuanos*, blue, in allusion to its prevailing color, and was also called by old writers *sappar*, from a corruption of sapphire, which the fine clear cyanites of deep tint sometimes resemble. It occurs generally in long prismatic or blade-like crystals, and is not uncommon in the gneissic rocks of New England and Southeastern Pennsylvania to North Carolina (Pls. XIII and XII, B). It presents various shades of blue and blue-green, occasionally varying to pure white, —the variety from the Tyrol called rhœtizite. Fine crystals occur with lazulite at Clubb's and Crowder's mountains, on the road to Cooper's Gap, in Gaston County, and also in Rutherford County. Cyanite is somewhat frequently associated with corundum, from which Dr. Genth believed it to be derived by alteration. Another locality is at Swannanoa Gap, in Buncombe County; but the finest specimens are found in Mitchell County,<sup>1</sup> where it occurs in distinct isolated crystals that, for perfection, depth of color, and transparency, rival those from St. Gothard, Switzerland. The locality is at an altitude of 5500 feet, near the summit of Yellow Mountain on the road to Marion, 4 miles southeast of Bakersville, in a vein of white massive quartz in a granitic bluff, associated with almandite garnet of a very light transparent pinkish-purple color. The vein has a dip of 60 degrees, bearing northeast and southwest. The color varies from almost colorless to deep azure-blue, as dark as the Ceylonese sapphire, also occasionally green. Some of the crystals are 2 inches long, while a few were observed  $\frac{3}{8}$  inch (15 millimeters) in width and  $\frac{1}{2}$  inch (10 millimeters) in thickness. Occurring in white quartz, they form beautiful specimens, and the loose crystals were extensively sold for sapphire some years ago, at Roan Mountain, the summer resort. A few

<sup>1</sup> Am. Jour. Sci., III, Vol. XXXVI. p. 224, Sept., 1888.

it seems remarkable that almost no tourmalines of this kind have been found in all the mining and prospecting work.

#### CHRYSOLEITE (OLIVINE, PERIDOT).

This mineral is a silicate of magnesia and iron. It occurs largely in an altered form in North Carolina, as the leading constituent of the decomposed peridotites called dunites, but very rarely in its unchanged condition. It is a green to yellow mineral, nearly as hard as quartz (6.5-7), and when transparent and in pieces of any size, it is valued as a brilliant gem-stone,—the chrysolite or peridot of jewelers. Near Webster, in Jackson County, it is found in granular masses, of a bright yellow-green color, and susceptible of a fine high polish. This material, if present in any quantity, might be utilized as a pleasing ornamental stone; but not as a gem, unless more transparent and in larger pieces.

#### *Analyses of Chrysolite from Webster, Jackson County, N. C.*

Constituent.	Per cent. <sup>4</sup>	Per cent. <sup>5</sup>	Per cent. <sup>6</sup>
Silica .....	41.89	40.74	41.17
Ferric Oxide } .....	0.58	1.83	.....
Chromic Oxide }			
Ferrous Oxide .....	7.39	7.26	7.35
Nickel Oxide .....	0.35	0.39	0.41
Lime .....	0.06	0.02	0.04
Magnesia .....	49.13	49.18	49.16

<sup>4</sup> F. A. Genth, analyst, *Am. Jour. Sci.*, III, 33, 200.

<sup>5</sup> *I. c.*

<sup>6</sup> F. A. Genth, analyst, *Am. Jour. Sci.*, II, 33, 199.

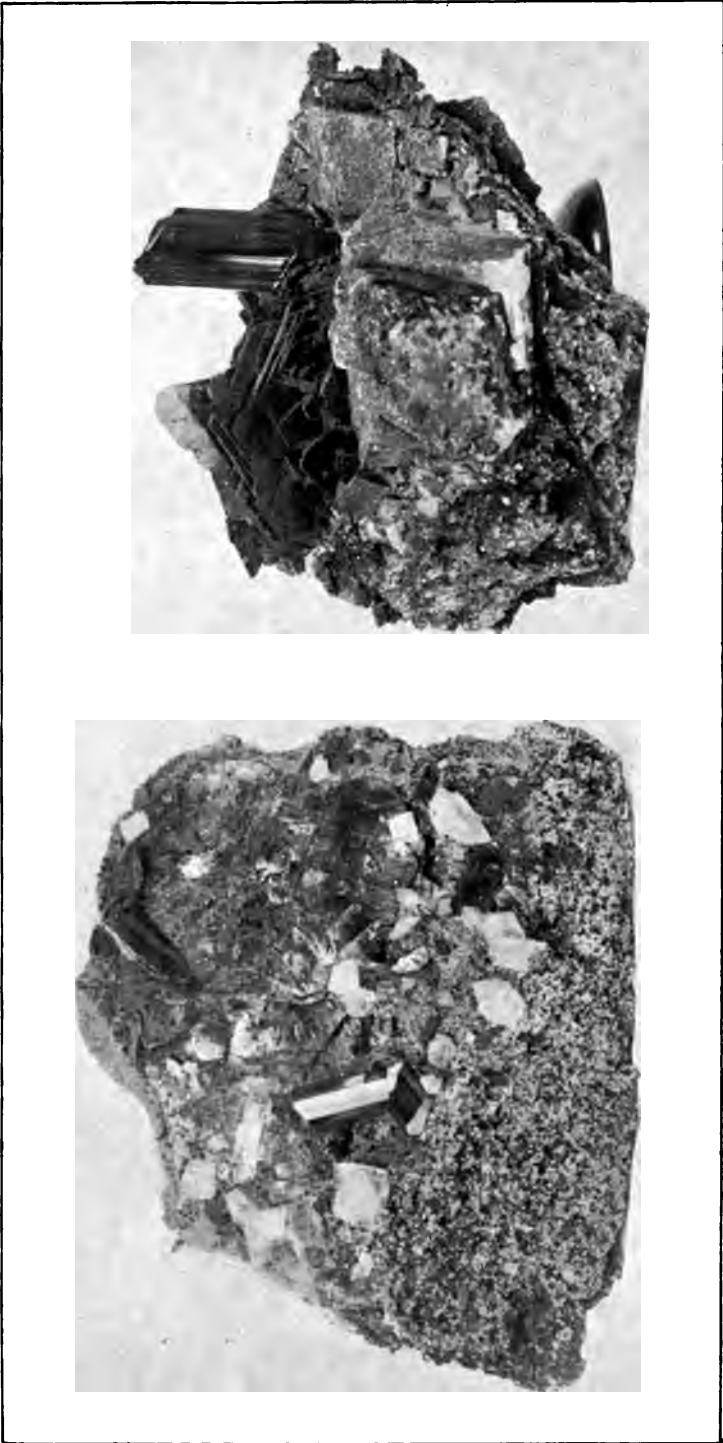
<sup>4</sup> Color, pale grayish green.

<sup>5</sup> and <sup>6</sup> Color, yellowish olive green.

#### SERPENTINE.

This mineral, a hydrous silicate of magnesia, occurs widely distributed throughout some portions of the State, and is often a result of the alteration of the olivine-bearing rocks (peridotite, dunite) already repeatedly mentioned. At some points it is massive and of good color and quality, such as might be used for building-stone, as it is frequently near Philadelphia. But the translucent and rich green variety known as precious serpentine, which is used as an ornamental stone like that of Maryland, has been recognized only at a few points and does not appear as yet to have been utilized at all. Dr. Pratt mentions several promising outcrops in Buncombe County, between Leicester and Weathersville, and others in Madison and Yancey counties. Still another, where the serpentine is of fine quality, is in Wilkes County, where it forms the rock of the asbestos





A. RUTILE, WITH DOLomite AND MUSCOVITE. B. RUTILE GROUP, NATURAL SIZE, STONY POINT, N. C.



mine near North Wilkesboro. It is hard and compact and polishes handsomely, and might prove as beautiful as that of Harford County, Maryland. Dr. Genth, also, years ago, stated that a serpentine from the neighborhood of Patterson, Caldwell County, of a dark greenish-black color, admits of a fine polish.<sup>†</sup>

*Analysis\* of Serpentine, Webster, N. C.*

Constituent.	Per cent.
Silica .....	43.87
Alumina .....	0.31
Ferrous Oxide .....	7.17
Nickel Oxide .....	0.27
Magnesia .....	38.62
Water .....	9.55

EDENITE (SMARAGDITE.)

Smaragdite is a variety of hornblende (amphibole), which occurs plentifully at the Cullakence Corundum Mine, Clay County, N. C. In color it is bright emerald to grass-green, also grayish and greenish-gray. Masses through which the pink and ruby corundum occur disseminated, are exceedingly beautiful. The mineral is hard enough to admit of a fine polish and is worthy of attention as an ornamental or decorative stone. It has recently been utilized for such purposes, under the name of "ruby matrix." Pieces are selected in which bright portions of red or pink corundum are enclosed in the rich green smaragdite, and the contrast makes a very attractive material. Smaragdite occurs also near Elf, on Shooting Creek, in the same county, similarly associated with corundum, pink and dark blue.

LAZULITE.

*Lazulite* is a somewhat rare mineral, a phosphate of alumina containing some magnesia and protoxide of iron. It occurs in pale and dark blue crystals and crystalline masses at Clubb Mountain and Crowder's Mountain, in Gaston County, and at Sauratown, in Stokes County. The finest crystals, however, come from Graves' Mountain, Georgia, some of them being as much as two inches in length. Its hardness is 6, and its specific gravity is 3.122. This mineral would make an opaque gem or an ornamental stone, as the color, though lighter, is often as rich as that of lapis lazuli, for which it was mistaken when first found.

<sup>†</sup> Mineral of N. C., p. 57.

\* F. A. Genth, analyst, Am. Jour. Sci., II, 33, 201.

*Analysis\* of Blue Lazulite from Gaston County, N. C.*

Constituent.	Per cent.	Per cent.
Phosphoric Acid .....	43.38	44.15
Alumina .....	31.22	32.17
Ferrous Oxide .....	8.29	8.05
Magnesia .....	10.06	10.02
Silica .....	1.07	1.07
Water .....	5.68	5.50
Hardness .....	5.0-6.0	5.0-6.0

## MALACHITE.

This beautiful green carbonate of copper, often used as an ornamental stone as well as mined for an ore of the metal, is found somewhat in Guilford, Cabarrus, and Mecklenburg counties. The fibrous variety has been observed at Silver Hill and at Conrad Hill, in Davidson County, and in a number of other localities in North Carolina, but is rarely of any gem value. In the Torrey Collection at the United States Assay Office, in New York City, are a few fine gem pieces of malachite from the Copper Knob mine in Ashe County.

## PEARLS.

The Indians of Carolina, Georgia, Florida and Alabama, gathered mussels and conchs, as shown by the numerous refuse piles and shell heaps that abound upon the salt-water creeks. It is not a matter of surprise that the Indians, as they opened these shells, should have carefully watched for pearls, and from the vast numbers examined, should have accumulated a store. If the shores of Carolina, Georgia, and Florida did not afford the larger and more highly prized pearls, it is not impossible that pearls from the islands and lower portions of the Gulf of Mexico, and even from the Pacific coast, may have found their way into the heart of Georgia and Florida and into more northern localities, to be there bartered away for skins and other articles. The replies of Indians to Father Hennepin and others and the presence in remote localities of beads, ornaments, and drinking-cups made of marine shells and conchs, still peculiar to the Gulf of Mexico, confirm the truthfulness of this suggestion.<sup>10</sup>

\* Analysts, Smith & Brush. Dana, Mineralogy, 5th ed., p. 572.

<sup>10</sup> Ancient Aboriginal Trade in North America, by Charles Rau. Report of the Smithsonian Institution for 1872, Washington, 1873; Gems and Precious Stones of North America, New York, 1890-92; U. S. Commission Fish and Fisheries, 1893-98; Pearls, by Geo. F. Kunz, Charles H. Stevenson, Century Co., New York, 1907.

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J. C. Branner

NORTH CAROLINA GEOLOGICAL SURVEY

J. A. HOLMES, STATE GEOLOGIST

BULLETIN No. 13

CLAY DEPOSITS AND CLAY INDUSTRY  
IN NORTH CAROLINA

A PRELIMINARY REPORT

BY

HEINRICH RIES



RALEIGH

GUY V. BARNES, PUBLIC PRINTER

1897









*Chamber*

**NORTH CAROLINA GEOLOGICAL SURVEY**

**J. A. HOLMES, STATE GEOLOGIST**

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STATE GEOLOGIST.

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## LETTER OF TRANSMITTAL.

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*To His Excellency, HON. D. L. RUSSELL,*  
*Governor of North Carolina*  
*and Chairman of the Geological Board.*

Sir:—I have the honor to transmit as bulletin 13 of the Survey series, a preliminary report on some of the clay deposits and the clay industry in North Carolina, by Dr. Heinrich Ries. This report is not intended as a complete or final discussion of the clay deposits of this State. Their examination has thus far been limited mainly to the regions about towns and railway stations, where the need for information is greatest; but during the next few years it is expected that this work will be extended to all portions of the State where there is a probability of discovering workable deposits of clay or kaolin.

Meanwhile it is thought best to publish, in response to the calls for immediate information, this preliminary report, which I regard as an important contribution to our series of reports on North Carolina resources. I believe it will be well received by the clay workers of the State, and hope that it will prove useful to them.

Yours obediently,

J. A. HOLMES,  
*State Geologist.*

RALEIGH, N. C.,  
July 15, 1897.

## PREFACE.

The following investigation of the North Carolina clays was undertaken for the purpose of determining (1) the extent, qualities, applicability of the clays occurring within the State; and (2) whether those deposits now being utilized could be used for making other or better products than those that are now being manufactured from them, by varying the mixtures or by the use of different appliances in the manufacture. The field work was carried on during the spring and autumn of 1896, and many of the clay deposits (nearly 100) were visited. Samples were collected from about seventy beds and submitted to chemical and physical investigation.

The chemical work was carried out in a careful and detailed manner by Prof. Chas. Baskerville, of the University of North Carolina. In each case the constituents determined were free and combined silica, alumina, ferric oxide, lime, magnesia, alkalies, moisture, and water. In certain cases determinations were also made of the ferrous oxide, organic matter, sulphur, and titanio oxide. Of the high grade clays, such as the kaolins, a *rational* analysis was made in each case. This, though of great importance, has rarely been done in this country, although it is often carried out abroad. From the rational analysis, as pointed out in the report, it is possible to compute the percentage of clay substance, quartz, and feldspar in the clay, a fact which is of great practical value to the manufacturer, for it gives him an important guide in making up the mixture for the body.

The physical investigations consisted in determining the amount of water required to be added to give a workable mass, the shrinkage in drying and burning of bricklets made from this mud; the color to which the clay burns; the temperatures of incipient fusion, vitrification, and viscosity; the cohesion or tensile strength of the air-dried clay, determined by making briquettes and pulling them apart in a cement testing

machine; the texture of the clay; the slaking in water; and other minor physical characteristics.

The fire tests were carried on in a regenerative gas furnace for temperatures up to 2500 degrees F., but for temperatures above this a Deville furnace was used.

The results of the work show that North Carolina contains an abundance of kaolin of superior quality, as well as clays for the manufacture of stoneware, pressed brick, sewer pipe, and probably paving brick if a mixture of clays is used.

The presence of good clays for the better grades of structural material is of itself a matter of importance, as at present nearly all such wares are brought from other States at considerable cost. While the sedimentary "bottom" clays yield smoother and usually better products than the residual ones, still experiments and practical tests show that the product made from the latter is materially improved by the proper manipulation.

Many of the products are easily accessible, being situated either along navigable rivers or near the intersection of important lines of traffic.

As only a portion of the clay deposits has as yet been examined, this must be regarded as a preliminary report. It is expected that these investigations will be continued until the more promising clay deposits in all parts of the State shall have been examined, and a final and more elaborate report will then be prepared for publication.

Acknowledgments are due to the clay workers of the State for the uniform courtesy with which they have aided the gathering of information for this report.

The American Clay-working Machinery Co., of Bucyrus, O., The Turner, Vaughn and Taylor Co., of Cuyahoga Falls, O., and the Director of the New York State Museum have kindly loaned several of the illustrations for this report.

HEINRICH RIES.

May 9, 1897.

# CLAY DEPOSITS AND CLAY INDUSTRY IN NORTH CAROLINA.

By HEINRICH RIES, Ph. D.

## CHAPTER I.

### THE ORIGIN OF CLAY.

Forming as it does one of the most abundant materials of the surface of the earth's crust, the enormously extensive application of clay is not to be wondered at. It is to be found almost everywhere, but varies greatly in form, color, and other chemical and physical characters. There are two properties, however, which are more or less constant, and by means of which clay can be generally recognized. These are plasticity when wet, so that any form can be given it by pressure; and the retention of this form when air-dried.

PURE CLAY is composed of the mineral kaolinite, which is a hydrated silicate of alumina, and masses of it are called kaolin. It rarely happens that kaolin is found in a strictly pure state, for more or less foreign mineral matter is usually present, and may form such a large percentage of the kaolin as to completely mask the kaolinite. The latter is known as the clay substance, the foreign minerals being regarded as impurities.

Clay may therefore be defined as a mixture of kaolinite with more or less quartz and other mineral fragments (hydrates, silicates, etc.) possessing usually plasticity when mixed with water, and when subjected to a high heat becoming converted into a hard, rock-like mass.<sup>1</sup>

KAOLINITE, the base of all clays, is not an original mineral of the earth's crust, but a secondary one, resulting from the decomposition of feldspars, and possibly sometimes from other aluminous minerals. The feldspars are a group of silicate minerals of rather complex composition, but orthoclase (the common feldspar), which serves as the type of the group, is a compound of silica, alumina, and potash, or in other words, a double silicate of alumina and potash.

The change to kaolinite is brought about by weathering agents of the atmosphere which are continually at work on the minerals of the earth's crust, disintegrating them or converting them into new min-

<sup>1</sup> The flint clays, though nearly pure kaolinite, possess little or no plasticity.

eral compounds. The most active weathering agents are oxygen and carbon dioxide, which by percolating waters are carried into the most remote cracks and crevices of the rocks, and attack the various mineral compounds, simply oxidizing some, decomposing others and carrying part of their elements off as carbonates, while silica may be left behind.

Under the action of these weathering agencies the feldspar is decomposed, the potassium being removed in the form of carbonate, while the silica and alumina remain behind, and with water form the hydrated silicate of alumina or kaolinite, whose composition is expressed by the formula  $\text{Al}_2\text{O}_3, 2\text{SiO}_2, 2\text{H}_2\text{O}$ ; or in the proportions of silica ( $\text{SiO}_2$ ) 46.3%, alumina ( $\text{Al}_2\text{O}_3$ ) 39.8%, water ( $\text{H}_2\text{O}$ ) 13.9%.

It sometimes happens that the percentage of alumina in clay is over 39.8, as in the case of many of the Missouri flint-clays, and Wheeler has suggested that they may be mixtures of kaolinite and pholerite.<sup>1</sup> The latter is an amorphous variety of the former and contains 45% of alumina.

The purity of a clay as formed will depend largely on the nature of the parent rock or the associations of the feldspar. This mineral frequently occurs in large vein-like masses, in which case its decomposition would yield a bed of nearly pure kaolin, but more frequently it is associated with quartz, or with quartz and mica, etc. When these pegmatite or granite veins decompose, the result is a bed of kaolin with particles of angular quartz and flakes of mica, etc., scattered through it. These mineral impurities can usually be separated by washing.

Beds of kaolin occurring in or very close to their place of origin are known as *residual clays*, and they may represent the purest as well as the most impure forms of clay. The mineral impurities commonly found in residual clays are feldspar, quartz, mica, garnet, hornblende, augite, rutile, etc. Residual clays may form small vein-like masses, or be of enormous extent. The kaolins near Webster and Sylva are examples of the former, the surface clays around Greensboro of the latter.

In the erosion of the earth's surface the residual clay is washed down into the lakes and seas, where it is deposited in the form of a sediment, but with the addition of many impurities.

Clays thus deposited are known as *sedimentary clays*, and are usually far more plastic than the residual clays mentioned above.

The clays of the Cretaceous and Tertiary formations bordering the Atlantic coast are all of sedimentary origin. Shales are simply hardened clays, their rock-like character being due to their having been buried more or less deeply under other sediments formed subse-

<sup>1</sup> Mo. Geol. Surv., XI, 1897.

to them. On grinding them to a powder and mixing them with water, they become plastic just like other clays.

By metamorphism a shale may lose its chemically combined water, develop a cleavage, and become converted into a slate. It is then no longer possible to develop any plasticity by grinding and mixing with water.

Sedimentary clays may vary widely in their nature, even in the same formation and within small areas. This is due to the variations in direction and velocity of currents in the bodies of water where they were deposited, for the finer clay would only be dropped in quiet water, while where currents existed coarse sand only might be deposited.

Variations in the current at the same point would produce alternating beds of clay and sand, while similar causes might develop large lenses of clay, free from sand or comparatively so, surrounded by coarse sand beds. The kaolin deposits of Aiken, South Carolina, and the black clays exposed in the bluffs at Prospect Hall, North Carolina, are examples of this.

Sedimentary clays may be either soft or hard. In the latter case they are known as shales. Shales, on account of their rock-like condition, are frequently deceptive, yet when ground and mixed with water they possess the same plasticity as soft clay. On account of the fusible impurities which they frequently contain, they are found to be admirably suited to the manufacture of vitrified wares, but in North Carolina no shale deposits have yet been developed which are suitable for the manufacture of clay products.

As clays show all gradations from the purest kaolins to the most impure brick clays, it is hard to draw any sharp lines of division between the kinds of clay used for one purpose or another, and consequently no classification is here given.

As before stated, kaolinite forms the base of all clays, and the rest of the clay is composed chiefly of the two minerals quartz and feldspar. The relative proportion of these three can not be calculated from the ordinary analysis, but if the amount of residue insoluble in sulphuric acid and sodium hydroxide be determined, and this latter analyzed for alumina, potash and soda, it is possible to calculate the amount of clay-base, quartz and feldspar present in the clay. This determination is of special importance in the case of clays used for the manufacture of porcelain, white earthenware, stoneware, tiles, and refractory wares.

The amount of clay-base may vary within wide limits. In a strictly pure kaolin it should theoretically be 100%, but seldom exceeds 90%. On the other hand, it may get as low as 5 or 10 per cent., and in this instance the material would resemble a sand more than clay. The percentage of feldspathic detritus is seldom large.

In kaolins of great purity the clay substance consists of kaolinite, but in impure clays the term is generally taken to mean the finest clay particles, viz., those under  $\frac{1}{8000}$  inches diameter. In impure clays the clay substance, which may contain both ferric oxide and lime, often forms the most plastic portion of the mass.

In the North Carolina clays the variations in clay substance and free sand (quartz and feldspar with some mica) are shown by the following extremes:

*Clay substance.*

Washed kaolin, Webster (53) .....	96.81%
Bottom clay, Prospect Hall (12) .....	85.02%
Crude kaolin, Bosticks Mills (20) .....	47.14%

*Free sand (quartz and feldspar).*

Black clay, Prospect Hall (12) .....	15.05%
Kaolin, Bosticks Mills (20) .....	52.86%



## CHAPTER II.

### CHEMICAL PROPERTIES OF CLAY.

The properties of clay are of two kinds, (1) chemical and (2) physical, and the action of clays under heat is not dependent on one class of properties alone, but upon both acting together. Two clays may correspond closely in chemical composition, but differ in their physical properties, and consequently act in a totally different way.

Pure clay, as previously stated, consists of the mineral kaolinite.

This is a white, pearly mineral, crystallizing in the monoclinic system, the crystals presenting the form of small hexagonal plates. Its specific gravity is 2.2 to 2.6, and its hardness is 2 to 2.5. It is naturally white in color, and plastic when wet, but very slightly so. A microscopic examination shows the plates of kaolinite to be collected in little bunches, which if broken apart by grinding increase the plasticity.<sup>1</sup> If kaolin be formed into briquettes of the same shape as those used in testing cement, its tensile strength, as determined by pulling these briquettes apart in a testing machine, is usually 12 to 15 pounds per square inch—a very low amount when compared with the tensile strength of more plastic clays. Kaolinite is practically infusible, as much so as silica or magnesite, but a slight addition of fusible impurities immediately lowers its refractiveness.

### IMPURITIES IN CLAY.

The impurities in clay are silica, iron oxides, lime, magnesia, potash, soda, titanitic acid, sulphuric acid, phosphoric acid, manganese oxide and organic matter.<sup>2</sup> They are generally present in the clay in the form of oxides, silicates, carbonates, sulphates, phosphates, etc. The minerals present in clay containing these impurities may be feldspar, quartz, limonite, mica, garnet, hornblende, augite, calcite, gypsum, talc, etc.

The impurities in a clay will vary in effectiveness according to the quantity present and the combination in which they exist. Thus calcium or alkalis if present as silicates may serve as a most useful flux, whereas if the calcium is present as carbonate it may be very injurious.

The impurities found in clay may be divided into two classes according to their effects: (1) fluxing impurities, and (2) non-fluxing ones.

<sup>1</sup> *The Clays of New Jersey*, N. J. Geol. Survey, 1878. G. H. Cook.

<sup>2</sup> All of these impurities are seldom present in the same clay.

**FLUXING IMPURITIES.**

These include alkalis, ferric oxide, lime, magnesia and silica. Their effectiveness or fluxing action is in the order given above; therefore, of two clays having the same physical properties and the same total percentage of fusible impurities, the one might be more fusible than the other on account of having a larger proportion of the more active of the fluxes in its composition. For some purposes it is desirable as well as necessary that the percentage of fluxes should be low, not only for reasons of refractiveness, but also to prevent discoloration of the ware, as when the clay is used for porcelain manufacture. On the other hand, when the clay is to be used for paving brick or sewer-pipe, a high percentage of fluxing impurities is desirable in order to produce a vitrified body. In kaolins the fluxes may be as high as 7%, provided they do not exert a coloring action. Thus some of the most celebrated porcelain kaolins have 35% of feldspar, which means about 5.5% of potash. In fire-clay 4 to 5% is the permissible limit, depending on the physical properties. For paving brick and sewer-pipe the total fluxes may run as high as 16%.

The term fluxing impurities should not be misunderstood. All the substances mentioned below as exerting a fluxing action do not become effective at the same temperature. Thus quartz is a flux at extremely high temperatures, while feldspar acts at a lower temperature, and iron or lime at a lower one still. Furthermore the greater the amount of feldspar present, the lower the temperature at which the quartz and kaolinite act on each other, for the feldspar when fused seems to play the same part that water does in promoting chemical action between two substances which when dry do not act upon each other.

**ALKALIES IN CLAY.**

The alkalis present in clays may be of two kinds, viz.: the fixed alkalis, potash, soda and lithia, and the volatile alkali, ammonia.

AMMONIA.—This substance is abundant in moist clay, and is absorbed by the latter with great avidity. Indeed, it is responsible to a large extent for the characteristic odor of clay.<sup>1</sup> If the ammonia remained in the clay it would act as a strong flux, but it is rendered harmless for the simple reason that it passes off as a vapor at a temperature considerably below dull redness, or may even volatilize with the moisture in the clay during the early stages of burning.

The fixed alkalis, POTASH, SODA, and LITHIA, will only vaporize at high temperatures, and consequently their effect must be taken into consideration in all stages of the drying and burning. Lithia is of very

<sup>1</sup> F. Senft, *Die Thonsubstanzen*, p. 29.

rare occurrence and only apt to be present in the rare mica, lepidolite; it may therefore be left out of consideration.

Potash and soda are present in almost every clay, from a trace up to nine or ten per cent., with an average of one to three per cent.

The reason for this variation is easily apparent when we consider the composition of pure clay and its derivation. Kaolinite, it will be remembered, contains only silica, alumina and water, whereas orthoclase, the common feldspar, has nearly 17% of alkalis. The presence in the clay, therefore, of varying amounts of undecomposed or even partly altered feldspar would be sufficient to account for the alkalis found in greater or less quantities in the majority of samples analyzed. Aside from the feldspar, the only common rock-forming mineral containing alkalis in abundance is mica. In a few cases potash or soda may be present in the form of soluble salts. We may, therefore, recognize two sources of the alkalis, viz., soluble and insoluble compounds.

#### SOLUBLE ALKALINE COMPOUNDS.

Soluble alkaline salts are very frequently present in clays, though generally in very small quantities. They may come from the decomposition of feldspar (as in the case of potassium carbonate), or may have been introduced by percolating surface waters. In most regions the soluble alkaline compounds are unimportant and hardly worth attention; but in areas of little rainfall, where evaporation exceeds precipitation, they become concentrated near the surface. These soluble salts may give the manufacturer considerable trouble. Unless decomposed in burning or rendered insoluble in some way, they may form an unsightly white coating on the surface of a burned brick or other product. In a similar manner this crust may interfere with the formation of a salt glaze by preventing the union of the sodium vapors with the silica of the clay, or prevent the glaze adhering to the surface of pottery which is glazed before burning.

Soluble alkaline sulphates are powerful fluxes. They may cause blistering of the ware if the clay is heated sufficiently high to decompose the sulphate and permit the escape of sulphuric acid gases.

In some clays containing sulphate of iron the latter may be decomposed by chemical reactions taking place in the clay and sulphuric acid set free. This acid is apt to attack the alumina of the clay-base, and, if potash, soda or ammonia are present, give rise to potash, soda, or ammonia alum, which can frequently be detected by tasting the clay.

#### INSOLUBLE ALKALINE COMPOUNDS.

The minerals feldspar and mica forming this class of alkaline salts in clay are among the commonest of the rock-forming minerals. The

feldspars are silicates of alumina and potash, or alumina, lime and soda. Orthoclase is the only species furnishing potash, of which it contains about 17%, while the lime-soda feldspars have from 4 to 12% of soda depending on the species.

The orthoclase is by far the commonest of the feldspars, and next to it in point of abundance come albite and oligoclase, with about 12% and 9% of soda respectively. The species of feldspars present in a clay may have some bearing on its refractiveness, for the soda feldspars are more fusible than the potash ones.

The micas are complex silicates of aluminium with iron, magnesium, and potassium. Muscovite, the commonest species of the group, contains nearly 12% of potash and may at times contain a little soda.

Feldspar is the only serious source of alkalis in clays, however, for the mica is not always present in very large amounts. Mica alone is extremely refractory, being unaffected at a temperature of 2550° F., while feldspar fuses completely at 2300° F.<sup>1</sup>

Alkalies, on account of their fluxing properties, especially if in the insoluble form as silicates, are frequently of an advantage, as they serve, in burning, to bind the particles together in a dense, hard body, and permit the ware being burned at a lower temperature. In the manufacture of porcelain, white granite and C. C. ware (cream-colored ware), the alkalies for fluxing are added to the body in the form of feldspar, provided the kaolin does not already contain a sufficient amount of this material. Much feldspar is mined in this country for potters' use, all of it being the potash feldspar.

So far as is known, the alkalies exert no coloring influence on the burned ware, although if an excess of feldspar be added to a white burning kaolin, the latter may exhibit a yellowish tint when burned.

In the North Carolina clays the combined alkalies (potash and soda) vary from .29% in clay from Spout Springs to 4.62% in brick clay from Wilkesboro. The average is 1.50 to 2.5%. The washed kaolins usually contain under one per cent. The pottery clays of North Carolina have from 0.68 to 2.82%.

#### COMPOUNDS OF IRON IN CLAY.

Aside from being a flux, iron oxide is also the great natural coloring agent of clays in both their raw and burned state. The mineral compounds which may serve as the sources of iron oxides in clays are as follows:

*Silicates:* Mica, hornblende, garnet, etc.

*Oxides:* Limonite, hematite, magnetite.

*Sulphides:* Pyrite, marcasite.

*Sulphates:* Melanterite.

*Carbonates:* Siderite.

<sup>1</sup>G. Vogt, Bull. de la Soc. Chim. de Paris; and Chem. News, 1890, p. 315.

The silicate mineral, mica, is missing in very few clays. Of the oxides, limonite and hematite are frequent impurities, and are often introduced from the surface by percolating waters, or may result from the decomposition of minerals, such as garnet. This fact is noticeable in some of the less pure portions of the kaolin beds at Webster, North Carolina. The iron oxides color the raw clay various shades of red and yellow. Pyrite is frequently present in clays, especially in many stoneware and fire-clays, its yellow, glittering metallic particles being easily recognizable. When disseminated through the clay in small grains it may be difficult to separate except by careful washing; but when occurring in lumps, popularly known as "sulphur balls," it is much easier to extract. If the finely disseminated pyrite remained in the clay, it would be found after burning that the clay was dotted with fused spots of silicate of iron. Many of the first speckled brick so extensively used at the present time were made in this manner.

The pyrite may readily become oxidized to the soluble sulphate of iron, which, if present in sufficiently large amounts, imparts an inky taste to the clay. Pyrite being such a strong flux, the addition of  $1\frac{1}{2}$  to 2% by weight, according to Wipplinger,<sup>1</sup> may exert a noticeable effect in the increase of its fusibility.

In all the classes of iron compounds mentioned above, the iron is present in one or two conditions, viz. as a ferrous or ferric salt; and the fusibility of the clay depends somewhat on this condition, ferrous salts being more fusible than ferric salts. In burning any clay the ferrous salt will be changed to the ferric salt, provided the action of the fire is oxidizing. If the fire exerts a reducing action, the same clay will, under these conditions, fuse at a lower temperature.

Ferric silicate may be an original mineral impurity of the clay, but many ferric compounds in clays result from the oxidation of ferrous carbonate or ferrous hydrate in clay which has been introduced in solution. The presence of ferric hydrate in clay increases its absorptive power for gases and solutions. On burning, the hydrate is of course converted into an oxide.

If treated to an oxidizing fire, the presence of ferrous salts need not therefore be considered, provided the heat is raised high enough to oxidize them. The rapidity with which the temperature is raised is important, for if the heat is raised too quickly the outer portion of the clay may shrink and become dense before the air has had time to permeate the clay and oxidize the iron in the centre of the body. This is the cause of black cores sometimes seen in bricks whose surface is red. This rapid heating may also bring about a differential shrinkage between the interior and exterior of the brick and cause cracking.

<sup>1</sup> *Keramik*, p. 26.

Unburned clays may be yellow, blue, brown, red or gray in color, depending on the relative amounts of ferrous and ferric salts present.

The same variety of shades and colors is produced in burning. Ferrous oxide ( $\text{FeO}$ ) alone produces a green color when burned, while ferric oxide ( $\text{Fe}_2\text{O}_3$ ) alone may give a purple, and mixtures of the two may produce yellow, cherry-red, violet, blue and black,<sup>1</sup> a fact which is of the greatest importance to manufacturers of unglazed wares. The more intense the heat the deeper the color produced by the iron.

Seeger<sup>2</sup> found that combinations of ferric oxide with silica produced a yellow or red color, while similar compounds of the ferrous salt showed blue and green.

The black coloration by iron produced by hard firing is often to be seen on breaking open the arch bricks of a brick kiln. The surface of these bricks may get black, due to the dust and ashes of the fire sticking to it.

The bleaching of the iron color by the presence of lime is to be seen in many calcareous clays, as described under lime. It may sometimes happen, however, that a calcareous clay when burned does not become buff, but shows a red surface, as if there were no lime present to neutralize the iron color.

In such an instance as found by Seeger, the core of the brick may show the expected buff color. This was brought about by the sulphuric acid vapors from the fuel uniting with the lime of the clay to form calcium sulphate, thus preventing its union with the ferric oxide.

The percentage of ferric oxide permissible or desirable in a clay depends on the quality of the latter. Kaolins, to be used in the manufacture of white ware, should have under 1% if possible, although many with 1.5% produce excellent results. A greater percentage might be present, provided there was also present three times as much lime to neutralize its color.

If a kaolin has enough ferric oxide to produce a faint yellowish tinge when burned, by burning it in a reducing atmosphere the color will be bluish, and will be far less noticeable. The reduction is accomplished by letting less air into the kiln, and the production of a smoky fire.

The North Carolina washed kaolins contain from .28% to 1.86%; the unwashed, 1.14% to 1.86%; the pottery clays from 2.88% to 5.48%.

The total range of ferric oxide in the seventy-three samples of North Carolina clays which were tested was from .28% to 11.79%, with an average of 1.5% to 5%.

#### LIME IN CLAYS.

Lime is a common detrimental or fluxing impurity of most medium or low grade clays. It may be present in one of three conditions, viz.:

<sup>1</sup> *Keramik*, p. 258.

<sup>2</sup> *Notizblatt*, 1874, p. 16.

- a. As a silicate, such as in the feldspars.
- b. As a simple carbonate, limestone or calcite, or in the form of a double carbonate, as dolomite.
- c. As a sulphate, such as gypsum.

The first two of these are primary mineral constituents of the clay, the third is of secondary origin and results from chemical action taking place in the clay.

The presence of lime as a silicate in clay is probably the form in which it usually occurs, especially if the clay has been derived wholly or in part from a region of feldspathic rocks. The common feldspar, orthoclase, contains no lime, so that it probably comes from the lime-soda feldspars. There are other silicates containing lime, but their presence is usually more difficult to prove with certainty.

When present as a silicate, lime acts as a flux, but it is less liable to exert a decolorizing action on the clay, by the formation of a double silicate of iron and lime, except at higher temperatures.

Calcium carbonate is very common in clays which have been derived in part from limestone areas, or it may result from the decomposition of lime-bearing feldspars. Its presence may be usually determined by treating the clay with muriatic acid, which produces effervescence if more than 4 or 5% of calcium carbonate is present.

Lime if present in the form of lumps or pebbles is very injurious, and should be removed by screening or washing. Finely divided lime though, if not present in too large amounts, may be harmless. Clays with 20 to 25% of calcium carbonate may be used for common or even pressed bricks, and also for earthenware. In the latter case the same clay can often be utilized for glazing the pottery, requiring only the addition of some fluxes.

#### EFFECT ON THE BRICK OF CALCIUM CARBONATE IN CLAY.

When occurring as carbonate in clay, lime becomes far more injurious. If the clay is underburned, the calcium carbonate will be simply broken up into carbon dioxide and lime. The former escapes, but the lime, on the cooling of the brick, slakes, that is to say, it absorbs water from the air, and swells, thus frequently bursting the brick.

If, however, the clay is thoroughly burned, the calcium carbonate after being decomposed unites with any free silicate that may be present and forms silicate of lime or probably also silicate of lime and alumina. If iron oxide is present, the lime takes it also into combination and thereby destroys its coloring action, giving a buff product instead of a red one, as would be the case if the iron oxide remained free. It should also be stated, however, that a low percentage of iron oxide in the clay without the presence of lime will also give a buff-colored ware. This is the case with many stoneware clays.

In high-grade clays large amounts of lime do not have to be considered, for such materials cannot be used, but in the manufacture of building brick, or pressed brick, terra-cotta, etc., it is frequently necessary to use a clay containing large percentages of lime, either from necessity or to obtain a cream-colored ware. It therefore becomes a matter of importance to know how much lime is permissible in a clay for this purpose. In general, it may be said that a good brick can be made from a clay containing 20 to 25% of calcium carbonate, provided it is evenly distributed through the clay and in as finely a divided state as possible.

Some clays contain lime in angular fragments or pebbles, which can be frequently removed by screening.

Aside from lowering the fusibility of a clay to a marked extent, lime also exerts a powerful effect on its shrinkage.

Seger<sup>1</sup> found that calcareous or marly clays required usually only 20 to 24% of water to convert them from a dry condition into a workable paste, whereas other clays needed 28 to 35% of water to accomplish the same change. Furthermore, as calcareous clays lost not only combined water but also carbon dioxide in burning, the bricks were the more apt to be light and porous, and this increased with the amount of lime present. They also shrink much less than other clays up to the points of incipient fusion. This low shrinkage may become zero, and the brick swell instead of shrinking. He also found that the difference between the points of incipient fusion and viscosity was so small that it was extremely difficult to bring a kiln of bricks made from calcareous clay to vitrification without melting a large number.

Seger claims that the presence of calcium carbonate and ferric oxide in the proportions of 3:1 is sufficient to produce a buff color.

Many clays contain calcium in the form of gypsum, the hydrated calcium sulphate. It generally originates from the action on calcium carbonate by sulphuric acid obtained by the oxidation and leaching of pyrite in the clay. Gypsum frequently discloses its presence by the formation in the clay of crystals or masses of its transparent variety, selenite. It also not uncommonly occurs in masses of parallel fibres filling cracks or cavities in the clay.

It serves as a flux, but may do considerable damage in burning by its disintegration, the sulphuric acid thus set free causing in its escape blisters on the surface of the wares.

There is another method by which lime may be introduced into clay, and that is absorption. This may occur when a clay deposit rests on a limestone or marl formation, and the lime being taken into solution by the percolating waters is soaked up by the clay. In this event the lower layers of the clay would be more calcareous than the upper ones.

<sup>1</sup> *Gesammelte Schrift*, p. 265.



Few of the North Carolina clays are very calcareous. Out of the seventy-three samples examined the lime varied from .1% in the clay at Prospect Hall to 2.55% in Kirkpatrick's clay at Greensboro. This latter is exceptionally high, for most of the North Carolina clays contain under 1%.

Its action, therefore, in all of the samples tested amounts to very little.

Marly clays are known to occur in the coastal plain formation near the coast, but none of these have been tested.

#### MAGNESIA IN CLAYS.

Magnesia rarely occurs in clays in the same quantity as lime; in fact, it rarely exceeds 2%. In the North Carolina clays, however, of which samples were examined it seldom exceeds .75%, and is generally present in about the same quantity as the lime.

Magnesia may be derived from the same classes of compounds as lime, viz. silicates, carbonates and sulphates.

The silicates are probably by far the most abundant form of its occurrence in clay and are represented by the minerals mica, chlorite, and hornblende (all scaly minerals) containing respectively 20-25%, 15-25%, and 15% of magnesia. The mica scales may be prominent in many clays, and chlorite scales, if very abundant, might even tend to color the clay green. Hornblende is mostly present in clays derived from rocks of a very basic composition (that is, with a low silica percentage), and the same may be said of pyroxene, which, however, is less common than the hornblende.

Dolomite, the double calcium-magnesium carbonate, has been mentioned under the description of lime (p. 21).

Magnesium sulphate, or epsom salts, occurs sparingly in clays. It is mostly to be found in those clays where sulphuric acid, set free by the decomposition of pyrite, has attacked magnesium carbonates. The presence of magnesium sulphate can frequently be detected by the bitter taste which it imparts to the clay.

As far as the effects of magnesia are concerned with the chemical properties of clay, they are probably the same as lime. This, however, can only be stated with a reasonable amount of certainty, for magnesia is generally present in such small amounts that its actual effect cannot be detected.

#### NON-FLUXING IMPURITIES.

These include silica, titanite oxide, organic matter, and water. Both silica and titanite oxide at high temperatures are fluxes.

## SILICA IN CLAYS.

Chemical analysis distinguishes two classes of silica, viz. (1) that combined with aluminium in kaolinite, and (2) sand. The latter includes quartz, and silica in combinations with various bases as in feldspar and mica (excluding kaolinite). The two kinds of silica included in this second class are insoluble in sulphuric acid and sodium hydroxide. If this residue be further analyzed, it is possible to calculate the amount of silica present as quartz and that contained in the clay in the form of feldspar or mica. This is frequently an important matter, for the condition of the silica may influence the fusibility of the clay to a marked degree.

Free silica or quartz is present in all clays in variable amounts. Cook<sup>1</sup> found a minimum of 0.2 of one per cent., and gives 5% as the average in the Woodbridge fire-clays. Wheeler<sup>2</sup> gives the minimum as 0.5 of one per cent. in the flint clays, and the sand as 20 to 43% in the St. Louis fire-clays, and 20 to 50% in the Loess clays.

Twenty-seven samples of Alabama clays contained from 5 to 50% of insoluble residue, mostly quartz.<sup>3</sup>

Seventy North Carolina clays had from 15.05 to 70.43% insoluble residue; while of three samples of which a rational analysis was run the percentage of sand was from 24.55 to 56.58%, and the quartz percentage in these ran from 16.58 to 49.06%, and the feldspathic detritus from 7.52 to 16.05%.

Free silica is considered by Bischof<sup>4</sup> to exert a fluxing action at high temperatures, that is, over 2800° F.

The most important effects of free silica and sand are directed towards the physical properties of clay. They lessen the plasticity, diminish the tensile strength and also the shrinkage. If silica is present in excess and in grains of large size, it may cause the clay to expand in burning. Quartz in fine grains lessens the shrinkage less than when present in large ones.

## TITANIUM IN CLAYS.

Titanium is probably of widespread occurrence in clay, though never present in great quantity; it may be derived from rutile (TiO<sub>2</sub>) or ilmenite (titaniferous iron ore). It was formerly looked upon as a rare element and a non-detrimental impurity, but this idea of its rarity has resulted from the fact that it is usually overlooked in chemical analyses. According to Seger, it is often present in clay slates and bauxites. Its effect on the refractiveness of a clay has always been misunderstood, although its action was considered similar to silica.

<sup>1</sup> N. J. Clay Rept., 1878, p. 213.

<sup>2</sup> Forthcoming Bulletin of Alabama Geological Survey.

<sup>3</sup> Mo. Geol. Surv., XI, p. 54.

<sup>4</sup> *Die Feuerfesten Thone*, 1896.

Although the determination of titanium in clay requires no difficult methods, it has, as a rule, not been determined in the chemical analyses of clay except when specially desired.

In order to determine definitely what the effect of titanium was, Seger and Cramer<sup>1</sup> took a sample of Zettlitz kaolin (which has 98.5% of clay substance) and mixed two samples of it with respectively 5% and 10% of silica, and two other samples of the kaolin with respectively 6.65% and 13.3% of titanitic oxide. These samples were molded into pyramids, which were heated to a temperature above the fusing point of wrought iron with the following results:

1. Pure Zettlitz kaolin burned to a white, sharp-edged, dense body.
2. 100 pts. kaolin and 10% silica burned white.
3. " " " " 5% " " "
4. " " " " 6.65% titanitic oxide softened in heating and showed a blue fracture.
5. " " " " 13.3% titanitic acid fused to a deep blue enamel.

It will therefore be seen that titanium acts as a flux at lower temperatures than silica, and calls to mind the fact that the blue color given to some stoneware clays by hard firing may not be due always to iron oxide.

#### ORGANIC MATTER IN CLAYS.

This is commonly noticed in many clays by the black color which it imparts to them, but the clay may also be colored brown or blue from the same cause.

The organic matter generally consists of finely divided pieces of plant tissue, or large pieces of stems and leaves, which settled in the clay during its deposition. All surface clays contain plant roots in their upper layers, but these do not always exert a coloring effect.

Clays colored by organic matter, and containing no iron, burn white as the plant tissue burns off at a bright redness, but if such a clay is heated too quickly the surface of the piece becomes dense before all of the organic matter has had time to escape from the interior, and the latter remains dark colored. The presence of iron may be masked by organic matter, so that the clay burns red, as is the case with the clays from Prospect Hill, on the Cape Fear river. Organic matter is seldom determined separately in chemical analysis, but its quantity may often be judged approximately from the relation between loss on ignition and alumina.

Organic matter exercises the important property of increasing the plasticity, but all clays having organic matter are not necessarily plastic, for the presence of much sand may render such a clay very lean, like the Prospect Hill clays.

<sup>1</sup> *Ges. Schr.*, p. 411.

## SILICA IN CLAYS.

Chemical analysis distinguishes two classes of silica, viz. (1) that combined with aluminium in kaolinite, and (2) sand. The latter includes quartz, and silica in combinations with various bases as in feldspar and mica (excluding kaolinite). The two kinds of silica included in this second class are insoluble in sulphuric acid and sodium hydroxide. If this residue be further analyzed, it is possible to calculate the amount of silica present as quartz and that contained in the clay in the form of feldspar or mica. This is frequently an important matter, for the condition of the silica may influence the fusibility of the clay to a marked degree.

Free silica or quartz is present in all clays in variable amounts. Cook<sup>1</sup> found a minimum of 0.2 of one per cent., and gives 5% as the average in the Woodbridge fire-clays. Wheeler<sup>2</sup> gives the minimum as 0.5 of one per cent. in the flint clays, and the sand as 20 to 43% in the St. Louis fire-clays, and 20 to 50% in the Loess clays.

Twenty-seven samples of Alabama clays contained from 5 to 50% of insoluble residue, mostly quartz.<sup>3</sup>

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**METHODS EMPLOYED IN MAKING CLAY ANALYSES.**

The following brief statement of the methods employed in making the analyses of clays for this report has been prepared by Dr. Charles Baskerville, by whom the analyses were made:

*Moisture.*—Two grams are heated in a platinum crucible at 100° C. until they show a constant weight. The loss is reported as moisture.

*Loss on Ignition* (combined water, and sometimes organic matter, etc.).—The crucible and clay are heated with a blast lamp until there is no further loss in weight.

*Alkalies.*—This same portion of clay, which has been used for determining moisture and loss, is treated with concentrated sulphuric and hydrofluoric acids until it is completely decomposed. The acids are evaporated off by heating upon the sand-bath. The cooled crucible is washed out with boiling water to which several drops of hydrochloric acid have been added. The solution after being made up to about five hundred cubic centimetres is boiled, one-half gram ammonium oxalate added and made alkaline with ammonium hydroxide; the boiling is continued until but a faint odor of ammonia remains. The precipitate is allowed to settle and is separated from the liquid by filtering and washed three times with boiling water. The filtrate is evaporated to dryness and ignited to drive off ammonium salts. The residue is treated with five cubic centimetres of boiling water, two or three cubic centimetres of saturated ammonium carbonate solution are added and the whole is filtered into a weighed crucible or dish. The precipitate is washed three or four times with boiling water and the filtrate evaporated to dryness. Five drops of sulphuric acid are added to the residue and then the crucible or dish is brought to a red heat, cooled in a desiccator, and the alkalies are weighed as sulphates.

To separate the alkalies, the sulphates are dissolved in hot water, acidified with hydrochloric acid, sufficient platinum chloride added to convert both the sodium and potassium salts into double chlorides; the liquid is evaporated to a syrup upon a water-bath, eighty per cent. alcohol added, and filtered through a Gooch crucible or upon a tared filter paper. The precipitate is thoroughly washed with eighty per cent. alcohol, dried at 100° C. and weighed; the potassium oxide is calculated from the double chloride of potassium and platinum.

When magnesium was present to as much as one-half of one per cent. the magnesium hydroxide was precipitated with barium hydroxide solution, and the barium in turn removed by ammonium carbonate. When the amount of magnesium was less than the amount named, this portion of the ordinary process was not regarded as necessary.

*Silica.*—Two grams of clay are mixed with ten grams of sodium carbonate and one-half gram of potassium nitrate and brought to a calm

In the weathering of clays, organic material, by its oxidation and consequent evolution of carbonic acid, helps to break up the clay.

#### WATER IN CLAYS.

The water in clay is of two kinds:

1. Hygroscopic water or moisture.
2. Chemically combined water.

**MOISTURE.**—This may be as low as .5% in air-dried clays or reach 30%-40% in those freshly taken from the bank. In the air-dried specimens of the North Carolina clays it ranged from .08% to 3.07% in the kaolins, .45% to 4.50% in the sedimentary clays, and .95% to 1.90% in the residual brick clays.

Air-drying expels most of the moisture in a clay, and this is accompanied by a shrinkage which, in 70 samples tested from North Carolina, ranged from 2% to 13.3%. Sandy, coarse-grained clays usually show the least shrinkage, but some of the fine-grained ones may act in a similar manner. The amount of water which a dry clay needs in order to develop an easily worked paste varies from 12%-20% in lean ones and 25%-35% for fat clays. The samples of North Carolina clays tested required from 16%-40%. The more water that a clay absorbs the more it has to part with in drying and the greater will be the shrinkage. If the clay is fine-grained, rapid drying may cause it to split from the active disengagement of steam.

In the manufacture of clay products the moisture is expelled by exposing the ware to the sun or drying it in heated tunnels. The last portions of moisture are driven off in the early stages of burning, known as water smoking, during which time abundant white vapors can be seen issuing from the kiln.

**COMBINED WATER** is present in every clay. In pure kaolin there is nearly 14% of it. In other clays the percentage varies with the amount of clay-base and hydrates present. In the North Carolina clays the loss on ignition (which practically amounted to combined water, those containing organic matter being left out) varied from 4.04% to 13.40% in the washed kaolins, 5.98% to 9.00% in the residual clays, and 4.17% to 11.08% in the sedimentary ones.

Combined water is driven off at a low red heat, and when this takes place the clay begins to suffer an additional loss in volume or shrinkage.

It is a curious fact that while the amount of combined water does not seem to stand in any close relation to the plasticity of a clay, nevertheless, when once driven off, the clay can no longer be rendered plastic by the addition of water. The fire shrinkage in the North Carolina clays varied from 2%-12%.

boiling water. The insoluble portion is filtered off, and after being thoroughly washed with boiling water is digested in fifteen cubic centimetres of boiling sodium hydroxide of ten per cent. strength. Twenty-five cubic centimetres of hot water are added and the solution filtered through the same filter paper, the residue being washed five or six times with boiling water. The residue is now treated with hydrochloric acid in the same manner and washed upon the filter paper, and free from hydrochloric acid, is burned and weighed as insoluble residue.

A portion of this is treated as the original clay for silica, aluminium oxide, and iron oxide. Another portion is used for the determination of the alkalis in the insoluble residue.

*Titanic Oxide.*—One-half gram clay is fused with five grams potassium bisulphate and one gram sodium fluoride in a spacious platinum crucible. The melt is dissolved in five per cent. sulphuric acid. Hydrogen dioxide is added to an aliquot part and the tint compared with that obtained from a standard solution of titanium sulphate.

*Sulphur* (total present).—The sulphur is determined by fusing one-half gram of clay with a mixture of sodium carbonate, five parts, and potassium nitrate, one part. The melt is brought into solution with hydrochloric acid. The silica is separated by evaporation, heating resolution, and subsequent filtration. Hydrochloric acid is added to the filtrate to at least five per cent. and the sulphuric acid is precipitated by adding barium chloride in sufficient excess, all solutions being boiling hot. The barium sulphate is filtered off and washed with hot water, burned and weighed as such.

*Ferrous Oxide* is determined by fusing one-half gram clay with five grams sodium carbonate, the clay being well covered with the carbonate, the top being upon the crucible. The melt is dissolved in a mixture of dilute hydrochloric and sulphuric acids in an atmosphere of carbon dioxide. The ferrous iron is determined at once by titration with a standard potassium permanganate solution.

The *rational analysis* is made from the results obtained by the chemical analysis in the following way: The alumina found in the portion insoluble in sulphuric acid and sodium hydroxide is multiplied by 3.51. This factor has been found to represent the average ratio between alumina and silica in orthoclase feldspar; therefore the product just obtained would represent the amount of silica that would be present in undecomposed feldspar. The sum of this silica with the alumina, ferric oxide and alkalis equals the "feldspathic detritus." The difference between silica as calculated for feldspar and the total silica in the insoluble portion represents the "quartz" or "free sand." The difference between that portion of the sample insoluble in sulphuric acid and sodium hydroxide and the total represents the "clay sub-

fusion in a platinum crucible over the blast lamp. The melt removed from the crucible is treated with an excess of hydrochloric acid and evaporated in a casserole to dryness upon a water-bath, and heated in an air-bath at  $110^{\circ}$  C. until all the hydrochloric acid is driven off. Dilute hydrochloric acid is added to the casserole now, and the solution brought to boiling and rapidly filtered. The silica is washed thoroughly with boiling water and then ignited in a platinum crucible, weighed, and moistened with concentrated sulphuric acid. Hydrofluoric acid is cautiously added until all the silica has disappeared. The solution is evaporated to dryness upon a sand-bath, ignited and weighed. The difference in weight is silica.

*Iron Sesquioxide.*—The filtrate from the silica is divided into equal portions. To one portion in a reducing flask is added metallic zinc and sulphuric acid. After reduction and filtration to free the liquid from undissolved zinc and carbon, the iron is determined by titration with a standard solution of potassium permanganate.

*Aluminium Oxide.*—To the second portion, which must be brought to boiling, ammonium hydroxide is added in slight excess, the boiling continued from two to five minutes, the precipitate allowed to settle and then caught upon the filter, all the chlorides being washed out with boiling water. The precipitate is ignited and weighed as a mixture of aluminium oxide and iron sesquioxide. The amount of iron sesquioxide already found is taken from this and the remainder reported as alumina.

*Calcium Oxide.*—The filtrate from the precipitate of iron and aluminium hydroxides is concentrated to about two hundred cubic centimetres, and the calcium precipitated in a hot solution by adding one gram of ammonium oxalate. The precipitate is allowed to settle during twelve hours, filtered and washed with hot water, ignited and weighed as calcium oxide. When the calcium is present in notable amounts, the oxide is converted into the sulphate and weighed as such.

*Magnesium Oxide.*—The filtrate from the calcium oxalate precipitate is concentrated to about one hundred cubic centimetres, cooled and the magnesium precipitated by means of hydrogen disodium phosphate in a strongly alkaline solution, made so by adding ten cubic centimetres of ammonium hydroxide (0.90 sp. gr.). The magnesium ammonium phosphate, after standing over night, is caught upon an ashless filter, washed with water containing at least five per cent. ammonium hydroxide, burned and weighed as magnesium pyrophosphate.

The *insoluble residue* is determined by digesting two grams of clay with twenty cubic centimetres of dilute sulphuric acid for six or eight hours on a sand-bath, the excess of acid being finally driven off. One cubic centimetre of concentrated hydrochloric acid is now added and



boiling water. The insoluble portion is filtered off, and after being thoroughly washed with boiling water is digested in fifteen cubic centimetres of boiling sodium hydroxide of ten per cent. strength. Twenty-five cubic centimetres of hot water are added and the solution filtered through the same filter paper, the residue being washed five or six times with boiling water. The residue is now treated with hydrochloric acid in the same manner and washed upon the filter paper, and free from hydrochloric acid, is burned and weighed as insoluble residue.

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stance." The method of analysis used to determine the mineralogical character of the clay is called the *rational* method, and when carried out in its simplest form, determines the amount of clay substance or kaolinite, quartz, and feldspar present in the clay. If carried out more completely it enables us to calculate the amount of calcite or limestone (calcium carbonate), iron oxide and even mica in the clay.

#### THE RATIONAL ANALYSIS OF CLAY.

In the ordinary or *ultimate* quantitative analysis of clay the latter is regarded as being composed of a given number of elements or oxides of them, in given amounts, but gives no clue as to the condition in which these substances exist, viz., whether they are present as oxides, silicates, carbonates, etc., a point which it is often of the greatest importance to know. Thus, as pointed out under calcium (Chemical Properties of Clay), if this substance is present as a carbonate it may be extremely injurious, but if combined with silica in the form of feldspar it is beneficial, serving as a binding material (p. 21). Or, again, the ultimate analysis does not point out the condition of the silica, whether present as quartz (serving to lessen the shrinkage) or as a constituent of feldspar (serving as a flux). A high percentage of total silica in an ultimate analysis may be caused by an excess of feldspar and not always by quartz.

The inferences which may be drawn from the ultimate analysis of a clay are:

1. It may be said in general that the greater the amount of ferric oxide in a clay the deeper red it will burn at any given temperature. Small percentages of ferric oxide will only color the clay yellow.
2. We can see from the ultimate analysis whether there is sufficient lime present to counteract the effect of the ferric oxide.
3. It is possible to gain an approximate idea of the fusibility of the clay from the total fluxes present, and also to see whether it is the weaker or more powerful fluxes that are present.
4. A very high silica percentage generally indicates a sandy clay.
5. Clays high in alumina and combined water as a rule shrink considerably in burning.

There are, however, many physical properties which the ultimate analysis does not explain, because they are dependent largely on the mineralogical composition.

It frequently happens that two clays show very close chemical composition, but act entirely unlike, and the explanation is almost self evident, viz., that the elements present in both clays are differently combined.

The following table of analyses illustrates this, viz.:

## CHAPTER III.

### PHYSICAL PROPERTIES OF CLAY.

These are fully as important as the chemical ones, and sometimes more so. In Germany the labors of Seger, Bischof, Olschewsky and others have brought forth the significance which the physical properties of clays have, and in this country the work of Orton and Wheeler has corroborated them in many details.

Chemical analysis alone cannot be used as a basis of comparison, but the physical characters must also be taken into consideration

While the list of physical properties may be made of considerable length, there are a number which are of special importance and will be considered herewith. These are plasticity, fusibility, shrinkage, tensile strength, slaking, absorption, density.

#### PLASTICITY IN CLAYS.

This is one of the most important properties of clays, for it permits their being molded into any desired form, which they subsequently retain.

Plasticity in clays is exceedingly variable. Those possessing little plasticity are called "lean," while those which are highly plastic are known as "fat" clays.

The cause of plasticity was for a long time supposed to be directly connected with the hydrated silicate of alumina, or kaolinite, and clays high in kaolinite were said to be very plastic and vice versa. This is plainly not so, as any series of clays tested will demonstrate.

Pure or nearly pure kaolins are very lean, while clays low in alumina may be highly plastic. This may be shown by a few examples drawn from the North Carolina clays tested, mentioning first that the tensile strength of a clay (as will be explained later) is closely related to its plasticity.

The examples to illustrate this point are as follows:

	Per cent. of Alumina.	Tensile strength in pounds per sq. in.	
		Average.	Maximum.
Lower clay, Roanoke Rapids (3) .....	16.09	206	218
Washed kaolin (53) .....	40.61	20	22
Clay, Spout Springs (17) .....	32.51	24	29

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<sup>1</sup> N. J. Geol. Survey, Rept. on Clays, 1878.

This mixture having less feldspar and clay substance, but more quartz, would probably show less plasticity and less shrinkage. Knowing, however, the rational composition of the Bostick kaolin, it is perfectly easy to add it in such proportions as will keep our mixture of the same composition.

In the manufacture of tiles, where one clay body is pressed on to another, it is highly essential that the two should have the same shrinkage to prevent cracking during the burning and cooling.

Experiments tend to show that if the two bodies have the same rational composition their shrinkages will be about the same, provided there is not much difference in the coarseness of their grain. In porcelain and white earthenware manufacture the clays are ground so fine that this point does not come into consideration.

A rational analysis has been made of all the North Carolina kaolins tested, and in the other clays the insoluble residue (quartz and feldspar combined) was determined.

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ture present in the clay, the plates sliding over each other and thus permitting mobility of the mass without cracking. As kaolinite is practically the only plate-like mineral omnipresent in the clay, the simple plate theory does not seem entirely sufficient.

Olschewsky<sup>1</sup> was probably the first to suggest that the plasticity and cohesion of a clay were dependent on the interlocking of the clay particles and kaolinite plates, and in this connection used the briquette method of testing the plasticity or rather obtaining a numerical expression for it, by determining the tensile strength of the air-dried clay.

The more recent experiments of W. Aleksiejew and P. A. Cremiatschenski on the Russian clays<sup>2</sup> show that plasticity is not only due to the interlocking of the clay particles, but also varies with the fineness of the grain, the extreme coarse and fine ones both having less plasticity.

In this country Wheeler's work on the Missouri clays has substantiated these views.<sup>3</sup>

Experiments by the writer on the Alabama clays<sup>4</sup> corroborate these results still further, and the tests of the North Carolina ones also point in the same direction. The clays southeast of Spout Springs, for example, which are very fine-grained, plainly show the lessening effect on the tensile strength.

Whether, however, the greatest tensile strength depends on the presence of particles of certain size, or a mixture of different sizes, and, if so, within what limits these sizes must be, is still to be determined.

Plasticity, whatever may be its exact cause, is an important property from a commercial standpoint, for it facilitates the molding or burning of the wares without cracking.

The amount of water required to develop the maximum plasticity varies. If too little is added, the clay cracks in molding and is stiff and hard to work. If too much water is used, the paste becomes soft and retains its shape with difficulty. Lean clays usually require less water to produce a workable paste than fat ones.

#### TENSILE STRENGTH OF CLAYS.

To state that the plasticity of a clay is lean, fair, good, or high is necessarily only approximate and unsatisfactory, and a method by which the degree of plasticity can be expressed accurately is much to be preferred.

Various methods for testing the plasticity of a clay have been devised, but as most of them are practically useless, if for no other reason than

<sup>1</sup> Töpf. w. Zieg., 1882, No. 29.

<sup>2</sup> Zap. imp. russk. techn. obschtsch., 1896, XXX, pt. 6-7.

<sup>3</sup> Mo. Geol. Surv., XI, 1897, p. 102.

<sup>4</sup> The Clay-working Industry in 1896, 18 Ann. Rept. U. S. Geol. Surv., pt. V, p. 1129.

that they are largely influenced by the personal equation, their discussion need not be gone into here, and any one desiring to look them up is referred to C. Bischof's work, "Die Feuerfesten Thone."

Two methods, however, approach the requirements:

The first consists in forming the clay into a bar of known section and then noting the load required to crossbreak it.<sup>1</sup>

The second, devised by Olschewsky,<sup>2</sup> consists in molding the clay into briquettes of the same shape as those used in testing cement, allowing them to air-dry, and then pulling them apart in a cement testing machine, noting the number of pounds pull required. Before breaking, the cross-section of the briquette must be carefully measured and the tensile strength per square inch calculated, as the clay shrinks in drying. This is a perfectly rational method and supposes that as plasticity is dependent on the interlocking of the particles, the tensile strength will naturally stand in direct relation to it. Even though it is not yet certain that this is the cause of plasticity, still it is certain that with increase in plasticity there is a rise in the tensile strength.

In the North Carolina clays the tensile strength varied from 5 lbs. per sq. in. in a Webster kaolin to 220 lbs. per sq. in. in a brick clay from Greensboro.

The residual clays tested were all of low tensile strength.

The clays were all ground to pass through a 30-mesh sieve before being molded into the briquettes.

#### SHRINKAGE OF CLAYS.

The variable shrinkage of clays in drying has already been mentioned in the discussion of water in clays. The amount of shrinkage depends somewhat on the amount of water absorbed or the porosity of the clays. But coarse-grained clays may absorb much water and yet shrink comparatively little. Having larger pores, they will permit the water to escape more rapidly, and hence can often be dried quicker than fine-grained ones, from which the water on account of the smallness of the pores cannot escape so quickly.

If fine-grained clays are dried rapidly, the surface shrinks quicker than the interior, and cracking may ensue, especially if the clay has a low tensile strength.

The air shrinkage begins as soon as the clay is molded and set out in the sun or put in a hot tunnel to dry, and continues until the moisture is driven off.

The fire shrinkage generally commences when the combined water begins to pass off, or about 1200° F. It varies just as the air shrinkage did.

<sup>1</sup> P. Jochem, *Zeitsch. der Verein deutsch. Ing.*, 1895.

<sup>2</sup> *Tüpf. Zeit.*, 1882, No. 26.

In the North Carolina clays the fire shrinkage was from 2-12%, with an average of 4-6%.

The fire shrinkage is influenced by several conditions, viz. amount of combined water, organic matter, and sand. The fire shrinkage increases with the amount of organic matter and combined water in the clay. Sand diminishes the shrinkage. Lime has the same tendency and may even make the clay swell a little. Clays containing a large amount of feldspar, will, instead of showing a steady shrinkage up to the temperature of complete vitrification or sintering, often exhibit a temporary increase of volume when the fusing point of the feldspar (about 2300° F.) is reached.

Between the points at which the moisture has ceased coming off and that at which the combined water begins to escape, the clay shrinks little or none at all. Consequently in firing a clay the heat can be raised rapidly between these two points, but above and below them it must proceed slowly to prevent cracking the ware.

#### FUSIBILITY OF CLAYS.

In the heating of a clay, or subjecting it to a gradually increasing temperature, it not only shrinks but begins to harden. After the moisture has been driven off the clay bears some handling and is moderately hard, but can be scratched by the finger-nail.

Accompanying the second shrinkage of the clay, beginning at a dull red heat, there comes an increase in hardness and density, and at a temperature of from 1500° to 2100° F., depending on the clay, it becomes very dense, the individual particles are barely recognizable, and the clay cannot be scratched with a knife. It is still porous, however. This is the point of *incipient fusion*. With an increase in the temperature of from 50° to 200° F., depending on the clay, an additional amount of shrinkage occurs. The clay becomes hard, dense, impervious, the particles are no longer recognizable, and the maximum shrinkage has been attained. This is the point of *vitrification* or sintering. With a further similar rise in temperature the clay becomes *viscous* or flows.

These three stages are not sharply marked, but with a little practice the eye can detect the condition which the burned clay has reached. With few exceptions, the point of vitrification seems to be midway between incipient fusion and viscosity. The difference in temperature between these two points varies from 75°-100° F. in calcareous clay up to 400° or more in the purer ones. Indeed, the majority of clays show a difference of 300°-400° F. between incipient fusion and viscosity.

The practical value of this property is at once apparent, for clays require to be heated to vitrification, and the greater the margin between this point and viscosity the better, for a kiln cannot be managed within very narrow limits of temperature.



## TEMPERATURE AT WHICH CLAY FUSES.

It may be said in general that, other things being equal, the fusibility of a clay will increase with the amount of fluxes.

This is only to be regarded as an approximate statement, for all the fluxing impurities do not act with the same intensity.

If the fluxes are the same, a fine-grained clay will fuse at a lower temperature than a coarse-grained one, because in a clay with fine grain the particles are closer together, and can interact better chemically when they become softened by the heat. This fact may be brought out by a comparison of the pipe-clay from the first pit at Pomona and that at Spout Springs.

The former is coarse-grained, and, though containing 5.10% of fluxes, only vitrifies at 2250° F., while the latter, with only 3.81% total fluxes, vitrifies at 2150° because it is very fine-grained.

Several attempts have been made to express the relative fusibilities of clays numerically, but none of them are wholly satisfactory, as they do not give a series of numbers expressing the relative fusibilities of different clays, which stand in the same order as the fusibilities themselves.

Until this can be done such formulæ have no definite value, and, in any case, it is more satisfactory to know the actual temperature of fusion of a clay than to express it in relative terms.

Bischof<sup>1</sup> assumed that refractoriness of a clay is directly as the square of the alumina and inversely as the silica and fluxes. He therefore deduced the formula in which F. Q. stands for "Refractory quotient."

$$F. Q. = \frac{(Al_2O_3)^2}{SiO_2 \times RO}$$

This only holds good for comparing clays of the same fineness. When there is a variation in this the formula no longer holds good.

Wheeler<sup>\*</sup> has suggested the formula

$$F. F. = D + \frac{N}{D'} + C$$

in which F.F. is called the Fusibility Factor.

N = sum of non-detrimentals, or silica, alumina, titanio acid, water, moisture and carbonic acid.

D = sum of detrimental impurities, or iron, lime, magnesia, alkalies, sulphuric acid, sulphur, etc.

D' = sum of alkalies which Wheeler supposes to have twice the fluxing value.

The formula without C was not much more regular in its results than Bischof's.

<sup>1</sup> *Die Feuerfesten Thone*, p. 71, 1876.

<sup>\*</sup> *Eng. and Min. Jour.*, LVII., 1894, p. 224.



## FUSION TEMPERATURES, ETC.—Continued.

No. of Cone.	Composition.		Fusion Point.	
			Cent.	Fahr.
26	0.3 K <sub>2</sub> O } 0.7 CaO }	7.2 Al <sub>2</sub> O <sub>3</sub> ·72SiO <sub>2</sub>	1650	3002
27	0.3 K <sub>2</sub> O } 0.7 CaO }	2.0 Al <sub>2</sub> O <sub>3</sub> ·200SiO <sub>2</sub>	1670	3038
28	Al <sub>2</sub> O <sub>3</sub> ·10SiO <sub>2</sub>		1690	3074
29	Al <sub>2</sub> O <sub>3</sub> ·8SiO <sub>2</sub>		1710	3110
30	Al <sub>2</sub> O <sub>3</sub> ·6SiO <sub>2</sub>		1730	3146
31	Al <sub>2</sub> O <sub>3</sub> ·5SiO <sub>2</sub>		1750	3182
32	Al <sub>2</sub> O <sub>3</sub> ·4SiO <sub>2</sub>		1770	3218
33	Al <sub>2</sub> O <sub>3</sub> ·3SiO <sub>2</sub>		1790	3254
34	Al <sub>2</sub> O <sub>3</sub> ·2.5SiO <sub>2</sub>		1810	3290
35	Al <sub>2</sub> O <sub>3</sub> ·2SiO <sub>2</sub>		1830	3326
36	Al <sub>2</sub> O <sub>3</sub> ·2SiO <sub>2</sub>		1850	3362

When these pyramids are placed in a kiln or furnace they begin to soften as the temperature is raised, and as it approaches their fusion point the cones bend over until the tip is as low as the base. When this occurs the temperature at which they fuse is considered to be reached.

If it is therefore stated that a clay vitrifies at cone 5, it means that the amount of heat required to make cone 5 bend over is sufficient to vitrify the clay. In this report it has not been thought advisable to use this method but to give the actual temperatures. Comparisons can be easily made by looking up the number of the cone in the foregoing table.

These cones are accurate to within 25°, which is entirely sufficient for practical purposes. In actual use the cones are set in the kiln at a point where they can be watched through a peep-hole but will not receive the direct touch of the flames from the fuel.

It is well to put two or more cones in so that warning can be had of the approach of the desired temperature.

In order to determine the temperature of a kiln, several cones of separated numbers are put in, as, for example, .07, 1, and 5. Suppose that .07 and 1 are bent over in burning, but 5 remains unaltered. The temperature of the kiln was therefore between 1 and 5. The next time 2, 3 and 4 are put in. 2 and 3 may be fused, but 4 remains unaffected. The temperature therefore reached the fusing point of 3, or 2174° F. If the cones up to about No. 2 are heated too quickly, they are apt to swell up, and prevent themselves bending over.

Seeger's cones are extensively used in Europe, and in America their application is extending. Their one great advantage is that they indicate not the actual temperature, but rather its action. Thus cone No. 1 does not bend over as soon as the temperature of 2102° F. is reached, but only when this temperature has penetrated the cone. It is not advisable to

## CLAY DEPOSITS IN NORTH CAROLINA.

## FUSION TEMPERATURES, ETC.—Continued.

No. of Cone.	Composition.			Fusion Point.	
				Cent.	Fahr.
02	0.3 K <sub>2</sub> O } 0.7 CaO }	0.2 Fe <sub>2</sub> O <sub>3</sub> } 0.3 Al <sub>2</sub> O <sub>3</sub> }	{ 3.90 SiO <sub>2</sub> 0.10 B <sub>2</sub> O <sub>3</sub>	1110	2030
01	0.3 K <sub>2</sub> O } 0.7 CaO }	0.2 Fe <sub>2</sub> O <sub>3</sub> } 0.3 Al <sub>2</sub> O <sub>3</sub> }	{ 3.95 SiO <sub>2</sub> 0.05 B <sub>2</sub> O <sub>3</sub>	1130	2066
1	0.3 K <sub>2</sub> O } 0.7 CaO }	0.2 Fe <sub>2</sub> O <sub>3</sub> } 0.3 Al <sub>2</sub> O <sub>3</sub> }	{ 4 SiO <sub>2</sub>	1150	2102
2	0.3 K <sub>2</sub> O } 0.7 CaO }	0.2 Fe <sub>2</sub> O <sub>3</sub> } 0.4 Al <sub>2</sub> O <sub>3</sub> }	{ 4 SiO <sub>2</sub>	1170	2138
3	0.3 K <sub>2</sub> O } 0.7 CaO }	0.05 Fe <sub>2</sub> O <sub>3</sub> } 0.45 Al <sub>2</sub> O <sub>3</sub> }	{ 4 SiO <sub>2</sub>	1190	2174
4	0.3 K <sub>2</sub> O } 0.7 CaO }	0.5 Al <sub>2</sub> O <sub>3</sub> 4SiO <sub>2</sub>		1210	2210
5	0.3 K <sub>2</sub> O } 0.7 CaO }	0.5 Al <sub>2</sub> O <sub>3</sub> 5SiO <sub>2</sub>		1230	2246
6	0.3 K <sub>2</sub> O } 0.7 CaO }	0.6 Al <sub>2</sub> O <sub>3</sub> 6SiO <sub>2</sub>		1250	2282
7	0.3 K <sub>2</sub> O } 0.7 CaO }	0.7 Al <sub>2</sub> O <sub>3</sub> 7SiO <sub>2</sub>		1270	2318
8	0.3 K <sub>2</sub> O } 0.7 CaO }	0.8 Al <sub>2</sub> O <sub>3</sub> 8SiO <sub>2</sub>		1290	2354
9	0.3 K <sub>2</sub> O } 0.7 CaO }	0.9 Al <sub>2</sub> O <sub>3</sub> 9SiO <sub>2</sub>		1310	2390
10	0.3 K <sub>2</sub> O } 0.7 CaO }	1.0 Al <sub>2</sub> O <sub>3</sub> 10SiO <sub>2</sub>		1330	2426
11	0.3 K <sub>2</sub> O } 0.7 CaO }	1.2 Al <sub>2</sub> O <sub>3</sub> 12SiO <sub>2</sub>		1350	2462
12	0.3 K <sub>2</sub> O } 0.7 CaO }	1.4 Al <sub>2</sub> O <sub>3</sub> 14SiO <sub>2</sub>		1370	2498
13	0.3 K <sub>2</sub> O } 0.7 CaO }	1.6 Al <sub>2</sub> O <sub>3</sub> 16SiO <sub>2</sub>		1390	2534
14	0.3 K <sub>2</sub> O } 0.7 CaO }	1.8 Al <sub>2</sub> O <sub>3</sub> 18SiO <sub>2</sub>		1410	2570
15	0.3 K <sub>2</sub> O } 0.7 CaO }	2.1 Al <sub>2</sub> O <sub>3</sub> 21SiO <sub>2</sub>		1430	2606
16	0.3 K <sub>2</sub> O } 0.7 CaO }	2.4 Al <sub>2</sub> O <sub>3</sub> 24SiO <sub>2</sub>		1450	2642
17	0.3 K <sub>2</sub> O } 0.7 CaO }	2.7 Al <sub>2</sub> O <sub>3</sub> 27SiO <sub>2</sub>		1470	2678
18	0.3 K <sub>2</sub> O } 0.7 CaO }	3.1 Al <sub>2</sub> O <sub>3</sub> 31SiO <sub>2</sub>		1490	2714
19	0.3 K <sub>2</sub> O } 0.7 CaO }	3.5 Al <sub>2</sub> O <sub>3</sub> 35SiO <sub>2</sub>		1510	2750
20	0.3 K <sub>2</sub> O } 0.7 CaO }	3.9 Al <sub>2</sub> O <sub>3</sub> 39SiO <sub>2</sub>		1530	2786
21	0.3 K <sub>2</sub> O } 0.7 CaO }	4.4 Al <sub>2</sub> O <sub>3</sub> 44SiO <sub>2</sub>		1550	2822
22	0.3 K <sub>2</sub> O } 0.7 CaO }	4.9 Al <sub>2</sub> O <sub>3</sub> 49SiO <sub>2</sub>		1570	2858
23	0.3 K <sub>2</sub> O } 0.7 CaO }	5.4 Al <sub>2</sub> O <sub>3</sub> 54SiO <sub>2</sub>		1590	2894
24	0.3 K <sub>2</sub> O } 0.7 CaO }	6.0 Al <sub>2</sub> O <sub>3</sub> 60SiO <sub>2</sub>		1610	2930
25	0.3 K <sub>2</sub> O } 0.7 CaO }	6.6 Al <sub>2</sub> O <sub>3</sub> 66SiO <sub>2</sub>		1630	2966

## FUSION TEMPERATURES, ETC.—Continued.

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27	0.3 K <sub>2</sub> O } 0.7 CaO }	2.0 Al <sub>2</sub> O <sub>3</sub> , 200SiO <sub>2</sub>	1670	3038
28	Al <sub>2</sub> O <sub>3</sub> , 108SiO <sub>2</sub>		1690	3074
29	Al <sub>2</sub> O <sub>3</sub> , 88SiO <sub>2</sub>		1710	3110
30	Al <sub>2</sub> O <sub>3</sub> , 68SiO <sub>2</sub>		1730	3146
31	Al <sub>2</sub> O <sub>3</sub> , 58SiO <sub>2</sub>		1750	3182
32	Al <sub>2</sub> O <sub>3</sub> , 48SiO <sub>2</sub>		1770	3218
33	Al <sub>2</sub> O <sub>3</sub> , 38SiO <sub>2</sub>		1790	3254
34	Al <sub>2</sub> O <sub>3</sub> , 2.58SiO <sub>2</sub>		1810	3290
35	Al <sub>2</sub> O <sub>3</sub> , 2SiO <sub>2</sub>		1830	3326
36	Al <sub>2</sub> O <sub>3</sub> , 2SiO <sub>2</sub>		1850	3362

When these pyramids are placed in a kiln or furnace they begin to soften as the temperature is raised, and as it approaches their fusion point the cones bend over until the tip is as low as the base. When this occurs the temperature at which they fuse is considered to be reached.

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These cones are accurate to within 25°, which is entirely sufficient for practical purposes. In actual use the cones are set in the kiln at a point where they can be watched through a peep-hole but will not receive the direct touch of the flames from the fuel.

It is well to put two or more cones in so that warning can be had of the approach of the desired temperature.

In order to determine the temperature of a kiln, several cones of separated numbers are put in, as, for example, .07, 1, and 5. Suppose that .07 and 1 are bent over in burning, but 5 remains unaltered. The temperature of the kiln was therefore between 1 and 5. The next time 2, 3 and 4 are put in. 2 and 3 may be fused, but 4 remains unaffected. The temperature therefore reached the fusing point of 3, or 2174° F. If the cones up to about No. 2 are heated too quickly, they are apt to swell up, and prevent themselves bending over.

Seger's cones are extensively used in Europe, and in America their application is extending. Their one great advantage is that they indicate not the actual temperature, but rather its action. Thus cone No. 1 does not bend over as soon as the temperature of 2102° F. is reached, but only when this temperature has penetrated the cone. It is not advisable to

use a cone a second time, in case it has not bent over in a previous burning. Such cones are apt to bend at a lower temperature.

In porcelain manufacture, cones of the same composition as the glaze on the ware are sometimes used.

These cones can be obtained for about one cent each from Prof. E. Orton, Jr., Ohio State University, Columbus, O.

#### SLAKING OF CLAYS.

When a lump of clay is placed in water it begins to slake or break up in a more or less characteristic manner, depending on the nature of the clay. Some homogeneous clays split into a number of angular fragments, others into scaly particles, while still others break up completely into their component grains. The rapidity of slaking varies, depending largely on the density and toughness of the clays. Some clays slake completely to pieces in two or three minutes, while others may lie in water for an hour or two and remain totally unaffected.

This property is of practical importance in two ways. In washing kaolins or stoneware clays it is desirable that they should fall apart quickly when thrown into water, and thereby permit a quicker and more thorough separation of the impurities.

Slaking is also of importance in tempering clays, for the easier they break up the easier and more thoroughly will they become mixed in the pugmill.

#### MINOR PHYSICAL PROPERTIES OF CLAYS.

The other physical properties of clay, such as absorption, fineness of grain, taste, color, have been mentioned in connection with other properties and need be but briefly referred to here.

#### ABSORPTION OF WATER.

The absorption of clays varies of course, some taking up a large amount of water, which they give off again in drying, with the risk of cracking the clay unless dried very slowly. The presence of organic matter, ferric hydrate and ammonia may increase the absorptive power. The residual clays common throughout the western half of the State often absorb a large amount of water, without showing much plasticity. They are coarse-grained and very porous, and show the property not uncommon to many clays, in that they become more plastic as water is added up to a certain limit, but a slight addition over this causes the clay to become soft and decrease rapidly in plasticity.

#### TEXTURE OF CLAYS.

Fineness of grain, as already mentioned, has an important bearing on the fusibility of clays. It also diminishes the tensile strength, and,

with few exceptions, requires the clay to be slowly dried, and in burning to be slowly heated at first. In porcelain manufacture the particles of clay must be of extreme fineness, and this has often to be brought about by grinding.

#### TASTE OF CLAYS.

Tasting a clay will often give a clue to the presence of soluble salts, such as sulphates of iron or magnesia, which may impart a bitter, inky taste to the clay. The presence of grit may also be detected by grinding a lump of the clay between the teeth.

#### COLOR OF CLAYS.

The color of a clay serves only as an indication of its quality within very wide limits.

Many high-grade clays which burn white are in their original or green state colored black by the presence of a small per cent of organic matter. The latter, however, may mask the presence of iron, as in those from Prospect Hall, which burn to a deep red.

Iron may color a clay green, yellow, red, gray, brown or black, depending on the condition of its compound, whether ferrous or ferric. In surface clays it frequently exists in the ferric condition as limonite or hematite, and imparts a brilliant yellow or red to the clay. Not unfrequently the upper part of a clay bank is yellow or red, due to the presence of abundant ferric oxide, while the lower portion of it may be blue or gray from the iron being less oxidized. Many kaolins with a very small percentage of ferric oxide burn white in oxidizing fire, but in reducing fire burn gray, due to a reduction of the iron from the ferric to the ferrous condition.

The colors imparted by the different constituents have been mentioned under the chemical properties. It should be remembered that in case the clay does not burn to a color which the analysis would indicate, that it may be due to the union of the elements in the clay with substances in the fire gases of the kiln. Many coals contain sulphur. In burning the sulphuric acid gases are apt to unite with the lime or other substances in the clay, with formation of sulphates.

#### DENSITY OF CLAYS.

The specific gravity of a clay varies with its mineralogical composition, and may run from about 1.75 to 2.60. Thus far it is not known of itself to have any practical value. In the summary of tests at the end of the report will be found the specific gravities of the North Carolina clays here described, determined by Prof. F. P. Venable.

## CHAPTER IV.

### GEOLOGY AND GEOGRAPHY OF NORTH CAROLINA CLAY DEPOSITS.

The clay deposits of North Carolina belong to two types, residual and sedimentary, which, with their varieties, may be grouped as follows:

- Residual:—Kaolins; fire-clays; and impure clays.
- Sedimentary: { Coastal plain clays, of Cretaceous or Tertiary age.  
Sedimentary surface clays (for brick and pottery), mainly along the streams and low-lands, in the Piedmont plateau and mountain counties.

The accompanying outline map (Plate II) indicates the general distribution of the geological formations in the State, except that no attempt is made to separate those of the coastal plain region.

#### RESIDUAL CLAYS.

These in general are to be found in any portion of the western half of the State, that being the area underlain by the granitic, gneissic, and schistose rocks from which they have originated by the decay *in situ*, as explained under the origin of clay.

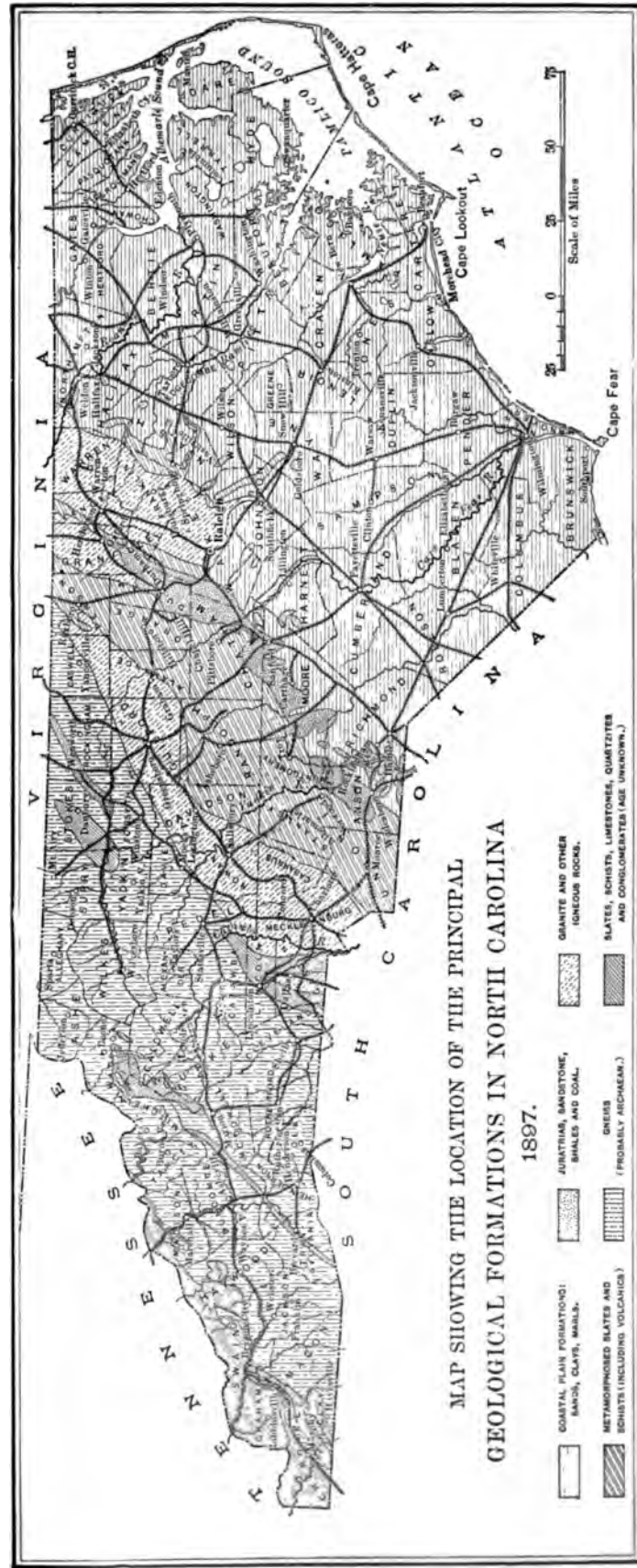
The eastern border of this area of crystalline rocks passes through the counties of Halifax, Franklin, Wake, Chatham, Moore, Richmond, and Anson.

West of this line, which passes near Weldon, Raleigh and Rockingham, we find the residual clays forming an almost universal mantle over the surface. They are generally coarse-grained, red, brown or yellow sticky clays, frequently of a lean character. Their thickness varies from three to twenty or more feet, depending on the depth to which disintegration of the rock has taken place and the amount of erosion of the surface that has occurred. In general, we may expect to find them of less thickness on the steep slopes than on the gentler ones or level areas.

It not unfrequently happens that the clay has been little disturbed and the banded structure of the gneiss or schist from which it originated may still be seen extending upward into the clay. As quartz decomposes more slowly than most rock-forming minerals, the veins of this material are also to be seen at times traversing the clay.

Residual clays commonly contain many angular grains and fragments of undecomposed or only partially decomposed mineral matter and the relative amount of this depends on the extent of the rotting the rock.







The brickmakers are very prone to use these materials on account of their sandy nature, their lean character making them much easier to work by hand; at the same time their porous nature produces a porous, weak brick unless properly burned, and at the smaller brickyards the burning is seldom carried far enough.

The composition of two of these impure residual clays is given below:

*Composition of Residual Clays.*

	Dean's Yard, Greensboro.	Greensboro Brk. & Tile Co.
Moisture .....	1.90	1.64
Silica .....	59.27	56.81
Alumina .....	22.31	20.62
Ferric oxide .....	6.69	6.13
Lime .....	.25	.65
Magnesia .....	.13	.58
Alkalies .....	.90	4.47
Water (loss on ignition) .....	9.00	8.60
Total .....	100.45	99.50
Free sand .....	33.35	40.65
Fluxes .....	7.97	11.83

The residual fire-clays found at Pomona and Grover are coarse-grained, sandy clays of a semi-refractory nature, with much intermixed quartz and mica. At times these two mineral impurities may become so abundant that the portions of the vein holding them have to be avoided in mining.

As these semi-refractory clay deposits have been but little worked thus far, not very much can be said of their extent. Vein formations such as they result from are often apt to be of a pocket-like nature, but at times are very extensive, so that they should be well exploited before much mining is done.

These residual clays are sometimes found such a short distance from their point of origin that they still practically possess their residual characteristics of leanness, coarseness, angularity of fragments, etc.

The kaolins, which also come under this head, are of the greatest commercial value. They result from the decomposition of feldspar or granite veins, so abundant in the crystalline area of North Carolina. In width they vary from a few inches to 300 feet, and the kaolin extends from the surface to a depth of 60 to 120 feet, depending on the extent to which the feldspar has altered. Below this the fresh or partially altered rock is met. In their unaltered state these veins may serve as sources of feldspar or quartz, which, when of sufficient purity, are available for potters' use.

The kaolin deposits at Webster, N. C., have been worked for a num-

ber of years to supply the potteries at Trenton, N. J., and East Liverpool, Ohio. The field work and laboratory tests carried on in connection with the preparation of this report indicate additional ones of a very promising nature.

#### SEDIMENTARY CLAYS.

The coastal plain deposits of North Carolina furnish the most extensive beds of clay to be found within the State. They have been classed as belonging to the Potomac (lower Cretaceous), Tertiary, and post-Tertiary (Columbia) formations.<sup>1</sup>

The former are best exposed along the Cape Fear river below Fayetteville, and consist of dark-colored clays, at times very sandy and frequently containing an abundance of organic matter.

The clay usually forms large lenses, and sometimes, by the increase of sand, passes into sand beds. One of the best exposures of these black Potomac clays is at Prospect Hall, 21 miles below Fayetteville; but they are exposed also in many of the river bluffs from 10 to 60 miles below Fayetteville (p. 102).

The Eocene deposits are best exposed along the western border of the coastal plain region in Moore and Harnett counties, lying near or at the summits of the sand hills and ridges. Their thickness varies from 5 to 15 feet, or possibly more, and there usually is but little (2 to 6 feet) of sandy overburden. The best known exposures of these are on the Sprunt lands, 2 to 3 miles north of Spout Springs, and 2 miles southeast of Southern Pines on the Seaboard Air Line Railway.

There are good exposures of clay in the cuts of the Cape Fear and Yadkin Valley R. R. between Spout Springs and Fayetteville, the age of which is not certain, though they are probably Eocene or Cretaceous.

The composition of these latter clays (see table at the end of report) might lead one to assign a refractory character to them, but their extreme fineness of grain causes them to fuse at comparatively low temperatures. Their smoothness is marked, and they might be used for other purposes.

Finely laminated clays of various colors are also to be found exposed in railway cuts and river bluffs in many parts of the coastal plain region, in some places associated with tertiary marls, and elsewhere overlying them. Along the western border of the coastal plain region, both in the river bluffs and on the divides between the streams, as are to be seen at intervals along the Atlantic Coast Line R. R. from Weldon to a few miles south of Fayetteville, are beds of finely laminated clays varying in color from yellowish to nearly black, and often mottled, which are believed to be a part of the Lafayette formation. None

<sup>1</sup> J. A. Holmes. "The Kaolin and Clay Deposits of North Carolina," *Trans. Amer. Inst. Min. Eng.* XXV, p. 929, 1896.

of these clays has yet been fully tested, but the results of their examination will be described in a later report.

There is also to be found in the terraces bordering the larger streams for some miles above and below where they pass from the hill country into the coastal plain region, a series of red and brown loams, which, near Weldon, Goldsboro and Fayetteville, in North Carolina, and at as many points similarly located in other Southern States, have been found to make good brick when properly manipulated. These "brick loams," as they have been designated, are of still more recent origin than the laminated Lafayette clays mentioned above, and they are classed with the youngest of our extensive geological formations, that known as the Columbia.

Many of the rivers farther inland, as they pass across the hill country, and even in the mountain region, are often bordered by considerable stretches of terrace which are underlain by brick or pottery clays, often of excellent quality.

The more sandy clays under these terraces are generally to be found close to the river, while the finer grained and smoother ones have been deposited nearer shore at the edge of the terrace, and when there are several terraces they are usually found under the upper one.

Such terraces are abundant along the Catawba river near Morganton and Mount Holly; along the Yadkin river, especially at Wilkesboro and Elkin; along the Clarke river (south fork of Catawba river) at Lincolnton, where clay to supply some fifty potters is dug.

It is from these terrace deposits of recent geologic age that some of the best clays in the State are to be obtained. In depth they vary from five to ten feet, and as some of these river valleys supply the lines of railroad with an easy passage through the mountain regions, the clays are well located for shipment either in their burned or unburned condition.

These river clays are also well developed along the French Broad river near Asheville; and at Biltmore they have produced excellent and extremely encouraging results.

It not uncommonly happens that the river terrace is formed on the slope of some hill covered by coarse-grained, lean, residual clays, and by the gradual creep of the soil the residual material moves down on to the sedimentary clay underlying the terrace. Such conditions are not uncommon, and at first sight the section of this kind exposed in a clay bank presents a rather peculiar appearance.

As mentioned above, the sedimentary clays are also well developed around Wilson, Goldsboro and Fayetteville.

With proper treatment, as will be mentioned later, these clays are capable of excellent results, and yet by careless methods the product that is sometimes produced is not fit to use.

Just as much care should be taken in the manufacture of brick as in white ware. There is, unfortunately, too much disposition to regard a brick as so many cubic inches of burned clay that must be able to stick together and little more.

The omnipresence of residual brick clays in the South has had an injurious effect on the clay-working industry, for when a large cotton mill or other building is erected the contractor generally digs up the nearest residual clay soil, the most siliceous he can find, and even then sand is sometimes added to it to permit its mixing with the minimum amount of labor.

This clayey sand is then molded by hand and hurriedly burned in small scove kilns. The great amount of sand naturally tends to make a porous brick, and burning the kiln barely to incipient fusion, and never much beyond, prevents the clay from reaching its maximum shrinkage. The result is a porous, soft brick.

The sedimentary clays generally make a smoother, denser brick, and one which burns at a lower temperature, but the residual brick clays are frequently capable of good results if properly handled.

Clays for making good common and pressed brick are of as much importance in North Carolina as stoneware clays and kaolins, for practically all the pressed brick now used in the State are shipped from other States.

#### THE NORTH CAROLINA CLAY-WORKING INDUSTRY.

The products at present manufactured in North Carolina include stoneware, earthenware, fire-brick, sewer-pipe, flue-linings, drain-tile and building brick.

Stoneware is manufactured by a number of small potters located chiefly in the western part of the State. The clays used burn to a dense hard body at moderate temperature, 2100° F., but the ware has a rough surface due to the glazing material, which contains much grit. The same potters make red earthenware articles to a limited extent. With the available clays there is room for much improvement in the character of the ware.

Fire-brick are manufactured at Pomona, Guilford county, Emma, Buncombe county, and Grover, Cleveland county. In each case the clays are coarse-grained, sandy ones, with much quartz and mica. Those at Grover especially would probably make a very good grade of refractory material, but their application has thus far been limited.

Sewer-pipe and flue-linings are only made at Pomona, Guilford county, but the factory located at that place is turning out a very good product, and it has recently been much enlarged.

Common brick are manufactured at many localities throughout the

State, but pressed brick have not passed beyond the experimental stage; although many of the clays are admirably adapted for this purpose, as those near Asheville, Buncombe county, at Wilkesboro, Wilkes county, around Goldsboro, Wayne county, and Raleigh, Wake county.

Many of these towns are at the intersection of several lines of railroad, so that the product could be easily shipped.

In visiting the various localities for the collection of samples for analysis and physical tests, this point has been borne in mind, and the areas most accessible have been especially examined.

## CHAPTER V.

### KAOLINS OR CHINA CLAYS.

#### CHARACTER, MINING, PREPARATION FOR MARKET.

North Carolina is one of the important producers of kaolin used by the manufacturers of white granite, C. C. (cream-colored) ware, and porcelain, at Trenton, East Liverpool and other localities in the United States, and the material produced stands second to none thus far mined in this country.

All of the North Carolina kaolins thus far discovered are of a residual nature, that is, the material is found at the point where it originated. They have resulted from the decay of veins of pure feldspar, pegmatite or granite, and vary in their initial impurity according to the number of foreign minerals which occurred in the vein from which they were formed.

#### DISTRIBUTION OF THE KAOLINS.

Knowing thus the nature of their origin, it is possible to predict approximately the limits within which they can occur. As the feldspar and granite veins are generally found cutting the gneisses, granites or hornblende and mica schists, the kaolin deposits can occur in any part of the central or western parts of the State, this being the area underlain by the crystalline rocks. Large deposits have thus far been recorded from Montgomery, Richmond, Cleveland, Burke, Jackson, and Macon counties.

#### MINERALOGICAL CHARACTER OF KAOLIN.

The kaolin from most of these veins is a white, dense, soapy substance, soft and easily picked out. Through this may be scattered scales of mica, garnet, quartz, etc. The mica is generally fresh in appearance unless it is an iron-bearing species. The garnet is almost invariably decomposed and forms rusty stains which can generally be eliminated in washing. The quartz is practically always undecomposed and in angular fragments. Its condition determines the necessity of its separation; that is to say, if the quartz were extremely fine its presence would be harmless. If the vein was originally a coarsely crystalline mass of quartz and feldspar, the former remains in such large fragments that it is necessary to eliminate it by washing; but if the quartz and



feldspar were intimately associated in a finely granular mixture, then the quartz may be scattered through the kaolin in the form of a fine siliceous powder, and if there are no other impurities with it, the quartz can be left in the kaolin.

Indeed, it sometimes happens that there is so much finely divided quartz present that it is impossible to separate all of it by washing. This is the case with the kaolin from Troy.

Depending, therefore, on the character of the quartz, the washed kaolin from different localities may show a very variable amount of clay substances.

In the case of the Webster kaolin the quartz forms a large mass in the centre of the vein, and is left standing while the kaolin is mined away on either side.

In Plate V, facing page 59, fig. 2 shows a bed of residual clay near Grover, and fig. 1 an extensive vein of residual kaolin near Webster.

#### PROPERTIES OF KAOLIN.

Kaolin of good quality is pure white when washed and dried, but often gray when wet. The purest North Carolina kaolin, and also other American kaolins, show on microscopic examination bunched and also isolated scales of kaolinite, plates and scales of white mica, grains of quartz, and apparently feldspar grains.

The plasticity of kaolin is usually very lean, although some crude kaolins are appreciably plastic to the feel. The tensile strength is always low, and in the North Carolina kaolins varies on the average from 5 to 20 lbs. per square inch. Most kaolins absorb considerable water in being worked into a plastic paste. They burn to a white body when little iron is present, and the hardness and density vary with the degree of temperature to which they are subjected, and also with the amount of quartz and feldspar which they contain. In the manufacture of china the kaolin is mixed with ball clay to give the mass plasticity, and feldspar to act as a flux. Quartz is also added to prevent excessive shrinkage. It is in this connection that the value of a *rational* analysis is felt.

The rational analysis considers a clay as being made up of quartz, feldspar, and kaolinite or clay substance, and shows the amount of each present in the clay. If now the potter changes from the kaolin he has been using to one from another locality, it will be possible for him, if he has a rational analysis of this new clay, to determine without endless experimenting how to vary the amount of quartz and feldspar which he adds to his mixture in order to produce one which, with the new kaolin, will give as good results as the old one.

The method of rationally analyzing clays is discussed under the "Chemical Analysis of Clay" (pp. 29-33), but a few points regarding it

may also be stated here. Clays may agree in their ultimate chemical composition, but disagree widely in their rational composition. Clays showing the same rational composition, will, other things being equal, usually have the same shrinkage. If they differ in the degree of fineness of their particles, they may show a different shrinkage, even though they analyze alike rationally. In porcelain and white earthenware manufacture the clay is generally ground so fine that this last point does not have to be considered.

A rational analysis has been made of the kaolins of North Carolina.

The fact that a kaolin does not contain 98% of clay substance need not cause the slightest uneasiness. The important requirement is a very low percentage of iron. If in addition to clay substance the clay contains quartz and feldspar, then just so much less quartz and feldspar will have to be added in making up the porcelain or other mixture. The celebrated French kaolins which do not have to be washed sometimes contain 38% feldspar.<sup>1</sup>

An examination of the following table shows that there is considerable variation in the proportion of clay substance, quartz and feldspar present.

*Table showing variation in clay substance, quartz and feldspar.*

Percentage of clay substance, quartz, and feldspar in North Carolina kaolins.

Locality.	Clay substance.	Quartz.	Feldspar.
Sylva (washed), N. Ca. Min. & Mfg. Co. (57)	94.21		5.75
Webster (washed), Harris Clay Co. (53)....	96.81	0.07	3.12
" (unwashed), G. Springer (54) ....	66.14	15.61	18.91
" (washed), G. Springer (56).....	93.24		6.60
Bostick Mills (unwashed) (21) .....	49.30	41.50	9.20
" " " (22).....	36.05		62.33
" " (washed) (20).....	54.30	43.85	1.82
Troy, darker kaolin (64a).....	14.71	83.94	1.91
" " " (64) (washed).....	20.83	76.20	2.34
" white kaolin (68) " .....	58.92	35.27	5.81
West's Mill, Macon Co., crude kaolin (69)...	83.39	14.98	1.58

It will be seen from the above that the free sand or insoluble residue in the North Carolina kaolins is nearly all quartz.

The variations in the total percentages of the washed samples is as follows:

*Variation in composition of kaolin, washed samples.*

Silica.....	44.08 to 86.03%
Alumina.....	6.46 " 41.70
Ferric oxide.....	.28 " 2.97
Lime .....	.15 " .50
Magnesia .....	.09 " .20
Alkalies.....	.25 " 2.48
Water (loss on ignition).....	2.90 " 13.56

<sup>1</sup> Seger's Ges. Schrift, p. 552.

The special point of interest in these analyses is the iron percentage. The per cent. of iron in the various washed kaolins and their color on burning are as follows:

*Table showing per cent. of ferric oxide in washed kaolin, and color on burning.*

Locality.	Ferric oxide, percentage.	Color of burned clay.
G. Springer, Webster.....	$\left\{ \begin{array}{l} .28 \\ \text{ \& 1.08 FeO.} \end{array} \right.$	White.
West's Mill .....	1.18	White.
Harris Clay Co., Webster.....	1.41	White.
Sylva.....	1.86	White.
Bostick Mills.....	2.14	$\left\{ \begin{array}{l} \text{White, faint} \\ \text{yellow tinge.} \end{array} \right.$
Dark kaolin, Troy.....	2.18	Light buff.
White kaolin, Troy.....	2.97	Red buff.

This affords an interesting series from which to determine the permissible limit of iron in a kaolin. It would seem from this that the extreme safety limit is 2%, but still under 1.5% is more desirable. It should be remembered that there might be 2 or 3% of ferric oxide without its presence being noticed, provided there was also present 6 to 9% of lime to bleach it. But still it is undesirable to have to count on this, and even if this condition existed the kaolin would burn yellowish white and not pure white.

#### MINING OF KAOLIN.

Kaolin is usually soft enough to be mined with a pick and shovel.

If the kaolin deposit is large and broad, it can be worked as an open pit, digging out the material with picks and shovels and loading it into wheelbarrows or cars, which are drawn or pushed to the washing troughs, or, if the pit is deep, brought to the foot of an incline and then hauled up by means of a cable.

Most of the North Carolina kaolin deposits are vein formations whose depth is comparatively great as related to their width. In such instances the method of sinking pits is adopted. This consists in sinking a circular pit in the kaolin about 25 feet in diameter. As the pit proceeds in depth it is lined with a cribwork of wood, as shown in fig. 2 of Plate III, which will be found facing page 56. This lining is extended to the full depth of the pit, which varies from 50 to 100 or even 120 feet. When the bottom of the kaolin has been reached the filling-in of the pit is begun, the cribwork being removed from the bottom upwards as the filling proceeds. If there is any overburden it is generally a good plan to use this for filling in the pits.

As soon as one pit is filled a new one may be sunk in the same manner right next to it. In this way the whole vein is worked out, and, if the

deposit is large, several pits may be sunk at the same time to increase the output of the mine.

The kaolin is taken from the pit in buckets, which are operated by a derrick. At the mouth of the pit it is discharged into barrows or cars.

Two other methods of mining may be mentioned.

If the deposit is deep and narrow, and the better portions of the kaolin are irregularly scattered through the vein, it may be cheaper to sink a shaft and run levels from this into the better parts of the bed. These levels generally have to be timbered and the shaft also requires lining.

Hydraulic mining has been tried with success in some very sandy, loose-grained kaolins, but is not used in North Carolina. The method as sometimes used consists in washing the clay down into the bottom of the pit, whence it is sucked up by means of a pump and discharged from the conveying pipe into the washing trough.

It is sometimes necessary to have a scraper to stir or loosen up the clay in order to permit its being sucked up more easily. Where applicable, this is a cheap and rapid method, but most kaolins are too dense and not sandy enough to permit its being used.

At the Harris Clay Company's mines, near Webster, the mines are at a higher level than the washing plant, and the kaolin, after being trammed for a few hundred feet from the mouth of the pits, is discharged directly into a trough leading down the slope to the washing works. A current of water is pumped up the slope and discharged into the trough to wash the kaolin down.

A kaolin bed to be of commercial value should not be less than 8 feet thick.

The workable depth depends on the distance below the surface to which the feldspar has kaolinized.

#### PREPARATION OF KAOLIN FOR MARKET.

Most kaolins are washed before shipment. This is done to eliminate coarse particles and substances such as iron, which would render the clay fusible or discolor it in burning.

Two methods of washing may be used. The first consists in throwing the kaolin into large circular tubs or "blungers" filled with water; in these tubs there revolve arms which stir the mass up to a mixture of creamy consistency. By this treatment the fine kaolinite particles and some very fine quartz, feldspar and mica grains remain in suspension while the coarser particles drop to the bottom. The water, with the kaolin in suspension, is then drawn off to the settling tanks.

A modification of this consists in the use of a large cylinder, closed at both ends. The cylinder is set in a horizontal position and contains an axis with iron arms, which as the axis revolves serve to break up the

clay. The latter is charged through a hopper, and a current of water passes into the end of the cylinder, while at the other end the water passes out with the fine clay particles in suspension, the coarser ones remaining in the cylinder.

The amount of water used has to be regulated by experiment. If an excess is used, too much coarse material will be washed out of the cylinder, and conversely if the current is too slow, the clay will not yield a sufficient percentage of washed material. The coarse sand remains in the cylinder and has to be removed from time to time, depending on the capacity of the cylinder and amount of coarse sand in the clay. When the water and suspended clay leave the machine they are conducted to the settling tanks.

This method is little used in this country for the purification of the crude material, although it is extensively used abroad.

The prevalent method of washing kaolin in the United States is by means of troughs, and the details of this method are as follows:

As the kaolin comes from the mine it is generally discharged into a log-washer. This consists of a semi-cylindrical trough, in which there revolves a horizontal axis bearing short arms. The action of these arms breaks up the kaolin more or less thoroughly, depending on its density, and facilitates the subsequent washing. The stream of water directed into the log-washer sweeps the kaolin and most of the sand into the washing troughs, which latter are about 15 inches wide and 12 inches deep. They may be wider and deeper if the kaolin is very sandy; in fact, they should be. The troughing is about 700 feet long, and to utilize the space thoroughly it is broken up into sections (50 feet each is a good length), these being arranged parallel, and connecting at the ends, so that the water, with suspended clay, follows a zig-zag course. This trough has a slight pitch in the North Carolina plants, being about one inch in 20 feet, but this is a matter depending on the kaolin. If the kaolin is very fine and settles slowly, the pitch need not be so great, and vice versa. A large quantity of very coarse sand in the kaolin is a nuisance, as it clogs up the log-washer and upper end of the trough more quickly, and causes so much more labor to keep them clear. As it is, considerable sand settles there, and, to keep the trough clear, sand wheels are used. These are wooden wheels bearing a number of iron scoops on their periphery. As the wheel revolves these scoops catch up a portion of the sand which has settled in the trough, and as each scoop reaches the upper limit of its turn on the wheel, it, by its inverted position, drops the sand outside of the trough. These sand wheels are a help, but it is very often necessary to keep a man in addition shoveling the sand from the trough.

A general view of the kaolin-washing plant at the Harris kaolin mine

near Webster is shown in Plate III, fig. 1. At the end of the shed on the right are the four sand wheels. Next to these comes the troughing, while in the lowest part of the illustration in front of the house are the settling tanks. In the background along the foot of the hill are the drying racks.

If the sand is finer it is not dropped so quickly, but distributed more evenly along the trough and does not clog it up so fast.

The zig-zag arrangement of the troughing has been objected to by some, as it produces irregularities in the current, causing the sand to bank up in the corners at the bends, and also at certain points along the sides of the troughing.<sup>1</sup>

The effect of this is to narrow the channel, and consequently increase the velocity of the current, thereby causing the fine sand to be carried still further towards the settling tanks.

This difficulty, which is not often a serious one, has been obviated either by having the troughing straight, or by allowing the water and suspended clay as it comes from the logwasher to pass through a section of straight trough, and from this into another one of the same depth but five or six times the width and divided by several longitudinal partitions. The water and clay then pass into a third section, twice as wide as the second, and divided by twice the number of longitudinal divisions.

By this means the water moves always in a straight course, but as it is being continually spread out over a wider space it flows with an ever decreasing velocity.

By the time the water has reached the end of the troughing nearly all of the coarse grains have been dropped and the water is ready to be led into the settling vats, but as a further and necessary precaution the water is discharged onto a screen of 100 meshes to the linear inch. The object of this is to remove any coarse particles that might possibly remain, and also to remove sticks and other bits of floating dirt that are sure to be introduced.

Two kinds of screens can be used: 1, stationary, and 2, revolving.

The stationary screen is simply a frame covered with 100-mesh copper cloth and set at a slight angle. The water and suspended kaolin fall on this and pass through. If they do not they run off the screen and are lost.

A slight improvement is to have two or three screens overlapping so that whatever does get through the first will fall on the second.

If the vegetable matter and sticks are allowed to accumulate they clog the screen up and nothing will run through. These stationary screens therefore have to be closely watched.

The revolving screens are far better, for they keep themselves clean.

<sup>1</sup> E. Hotop. *Thonindustrie Zeitung*, 1898.



FIG. 1.—KAOLIN WASHING AND DRYING PLANT, HARRIS CLAY CO., NEAR WEBSTER.  
(See also page 61.)



FIG. 2.—KAOLIN MINE, HARRIS CLAY CO., NEAR WEBSTER.  
Showing method of sinking pits in the soft kaolin. (See pages 53 and 60.)





Such a screen is barrel-shaped, and the water, with the kaolin in suspension, is discharged into the interior and passes outward through the screening. As the screen revolves, the dirt caught is carried upwards and finally drops; but instead of dropping down upon the other side of the screen, it falls upon a board which diverts it out on to the ground.

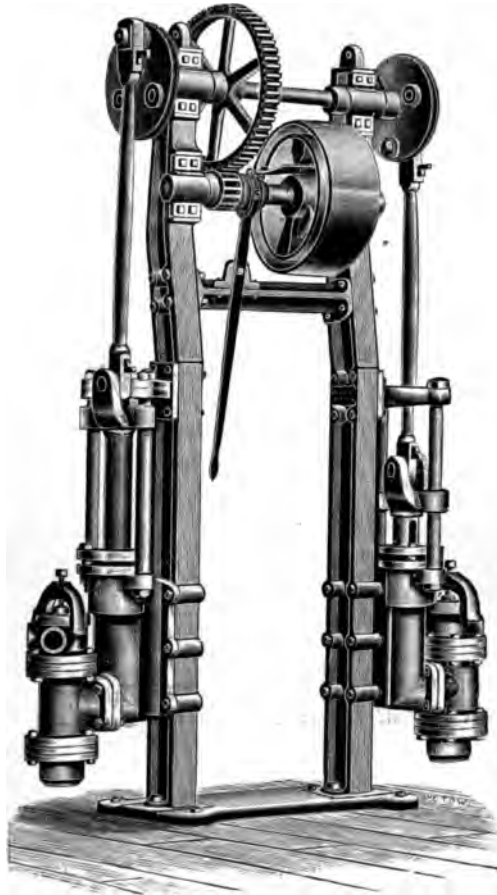


FIG. 1.—PUMP USED IN FORCING KAOLIN SUSPENDED IN WATER FROM THE  
SETTLING VATS INTO THE PRESSES.

The settling tanks into which the kaolin and water are discharged may be, and often are, about 8 feet wide by 4 feet deep and 50 feet or more long. As soon as one is filled the water is diverted into another.

The larger a settling tank, the longer it will take to fill it and allow the kaolin to settle, and delays due to this cause are expensive, especially when the market takes the output of washed kaolin as soon as it is ready. Too many small tanks increase the initial cost of plant.

If the kaolin settles too slowly, alum is sometimes added to the water to hasten the deposition. When the kaolin has settled most of the clear water is drawn off, and the cream-like mass of kaolin and water at the bottom of the vat is drawn off into the slip pumps and forced by them into the presses. Figure 1, on the preceding page, shows a form of pump used for this purpose, made by the Turner, Vaughn and Taylor Company of Cuyahoga Falls, Ohio.

The presses consist simply of a series of flat iron or wooden frames between which are flat canvas bags. These bags are connected by nipples with the supply tube from the slip pumps. By means of the pressure from the pumps nearly all of the water is forced out of the kaolin and through the canvas.

When all the water possible is squeezed out the pressure is removed, the press opened, and the sheets of semi-dry kaolin taken out. These sheets are rolled up and put on the racks out in the open air or in a steam-heated room to dry.

Plate IV, fig. 1, shows a kaolin filter press with wooden frame and fig. 2, such a press with an iron frame. The latter is preferable especially in climates where wood decays easily.

In a plant of steady and moderate capacity, both economy and ease may be practised by paying a little attention to its proper arrangement.

It is a good idea to have cars on a track, or an endless belt run past the presses and drying racks. The clay can then be taken right from the presses and put on the cars or belt and taken right from them and put on the racks.

As for every ton of crude kaolin usually only about two-fifths or sometimes one-quarter of a ton of washed kaolin is obtained, the importance of having the washing plant at the mines will be easily seen, for it avoids the hauling of 60 to 70% of useless sand, which has to be washed out before the kaolin can be used or even placed on the market.

#### DEPOSITS OF KAOLIN IN NORTH CAROLINA.

##### KAOLIN IN JACKSON COUNTY.

NEAR SYLVA.—North Carolina Mining and Manufacturing Co. The kaolin mine of this company is two miles south of Sylva on the mountain slope. The wall rock is a gneiss, now largely decomposed to a ferruginous clay. The kaolin vein cuts this, striking about N. 45° E. Its exact width is not known, but it is 8 to 10 feet in places. A 50-foot shaft has been sunk on the vein, and from the foot drifts have been run in both directions along the vein. This drift is about 4 feet wide and 6 feet high. That running to the east from the shaft is about 15 feet long, including two offsets due to faulting of 16 feet each. The



FIG. 1.—WOODEN FRAME FILTER-PRESS. FOR REMOVING THE WATER FROM THE WASHED KAOLIN.



FIG. 2.—IRON FRAME FILTER-PRESS, FOR REMOVING THE WATER FROM THE WASHED KAOLIN.







FIG. 1.—RESIDUAL KAOLIN DEPOSIT, HARRIS CLAY CO., WEBSTER.

View looking N. E. along the strike, shows only half of the vein, the rock on the left being a large lens of quartz in the center of the vein.



FIG. 2.—RESIDUAL CLAY DEPOSIT, NEAR GROVER.

Belonging to the Powhatan Clay Manufacturing Company. (See page 82.)

drift running west has gone only a short distance. A second tunnel was started towards the east, about 8 feet above the bottom of the shaft.

There are streaks of so-called "sand" at several points in the mine, which are patches of only partially kaolinized rock. Several tons of fresh feldspar have been shipped from this mine. The washed clay is very fine-grained with no grit. Color pure white. Very smooth. Slakes slowly but very completely. To produce a workable paste 40% of water was required. This paste was lean, and shrunk 8% in drying and 4% in burning, giving a total shrinkage of 12%. The tensile strength of air-dried briquettes made from this paste was 15 lbs. per square inch.

Incipient fusion occurs at 2200° F., vitrification at 2450° F., and viscosity at 2700° F.

The clay burns to a pure white, smooth body.

The shrinkage in drying and burning is 3% less than in the case of the kaolins from Florida.<sup>1</sup>

The following is the analysis of this clay:

*Analysis of washed kaolin (No. 57) N. C. Mining & Mfg. Co., two miles south of Sylva.*

Moisture .....	3.07
Silica (total) .....	44.08
Alumina .....	36.26
Ferric oxide .....	1.86
Lime .....	.43
Magnesia .....	.20
Alkalies .....	.50
Water (loss on ignition) .....	13.56
<hr/>	
Total .....	99.96
Free sand .....	5.73
Total fluxes .....	2.99

*From this analysis we get:*

Clay substance .....	94.21
Quartz and feldspar .....	5.73

Specific gravity ..... 2.31

The insoluble residue was not analyzed separately, as there was such a small amount of it.

From the analysis it will be seen that the clay contains a high percentage of clay substance.

**NEAR WEBSTER.**—Harris Clay Company. The kaolin deposit of this company is a large and very coarse pegmatite vein or dike with a maximum thickness of nearly 300 feet. In the middle there is a large thick lens of quartz. (Plate V, fig. 1.)

<sup>1</sup> Langenbeck, *Chemistry of Pottery*, 101.

The vein runs almost north and south, and the kaolin is of high quality, but has some quartz and mica, and occasionally garnet mixed in with it.

The wall rock is a reddish, fine-grained, much decomposed gneiss, and the boundary between the kaolin and gneiss is not always sharp. There are really three distinct "veins" of kaolin included in the 300 feet mentioned above. A tunnel was driven across a portion of the deposit from west to east, and the materials which were passed through, together with their thickness, were as follows:

*Section across the Harris Kaolin Mine near Webster.*

Kaolin .....	28 ft.
Gneiss .....	23 "
Quartz .....	32 "
Kaolin (exposed in V tunnel).....	56 "
Kaolin (bored through) .....	21 "
Kaolin (exposed in shaft) .....	22 "
<hr/>	
182 ft.	

The 21 feet exposed in boring were through kaolin, and ended in a shaft 22 feet wide sunk in the eastern half of the vein. There were several feet of kaolin beyond this shaft, giving over 100 feet of solid kaolin in the eastern half of the vein. The tunnel was about 70 feet below the surface.

The pits sunk in the kaolin vary from 15-25 feet in width and 80-100 feet in depth. The deepest thus far sunk is 125 feet through solid kaolin. (Plate III, fig. 2, p. 56.)

Since April, 1896, the company has been following the strike of the vein down the hill, toward the north, and has sunk several new pits in this direction.

The washed kaolin from this mine is smooth to the taste and feeling and shows little or no grit. In water it falls slowly but completely to a fine powder. Forty-two per cent. of water were required to give a workable paste, which was somewhat lean. It shrunk 6% in drying and 4% in burning, giving a total shrinkage of 10%. The average tensile strength of air-dried briquettes was 20 lbs. per square inch with a maximum of 22 lbs. Incipient fusion occurred at 2300° F., vitrification at 2500° F., and viscosity above 2700° F.

The clay burns to a white body. The ultimate and rational analysis of this kaolin yielded the following results:



*Analysis of Kaolin (No. 53), Harris Clay Co.'s Mine, Webster.*

	Washed kaolin.	Portion insoluble.
Moisture .....	.35	....
Silica .....	45.70	2.00
Alumina .....	40.61	0.55
Ferric oxide .....	1.39	0.27
Lime .....	0.45	....
Magnesia .....	0.09	....
Alkalies .....	2.82	0.37
Water (loss on ignition) .....	8.98	....
Total .....	100.39	3.19
Free sand .....	3.19	....
Total fluxes .....	4.75	....
Specific gravity .....	2.43	....

*This gives the following:*

Clay substance .....	96.81
Quartz .....	0.07
Feldspar .....	3.12
	100.00

The kaolin as mined is discharged into the upper end of a trough, along which it is washed down to the works. It is discharged into the upper end of the washing troughs, and, with the water, passes along under 5 sand wheels, which extract a large amount of the fine sand and keep the trough from becoming clogged. The kaolin, sand and water then pass along 700 feet of troughing, gradually dropping the sand, until the settling tanks are reached. There are 3 troughs, 4 pumps and 4 presses, open-air drying racks, and a steam-drying room. The capacity of the works is 24 tons per day of washed and dried kaolin. (See Plate III, p. 56.)

The washed kaolin has to be hauled four miles to the railroad at Dillsboro. The clay is dried in the steam chamber in three days, while on the racks it requires two weeks.

**SPRINGER CLAY PIT.**—Geo. Springer, Jr., has recently opened a mine of kaolin on the property of Wm. Buchanan, one-half mile northeast of Webster. A drift has been run in from the side of the hill and across the vein. In this tunnel the vein of kaolin shows up 25 feet wide and strikes N. 15° W.

Two headings have been run north and south from the drift for a distance of five feet. About 50 tons of the crude material have been thus far taken out.

The kaolin appears to be of excellent quality, but the presence of some coarse angular quartz fragments necessitates its washing.

Both the crude and washed clays were tested, and the two series of tests are given in parallel columns for the sake of comparison. No. 54 is the crude material and No. 56 the washed kaolin.

*Physical tests of Kaolin, washed and crude, Springer pit.*

	No. 54. Crude kaolin.	No. 56. Washed kaolin.
Character .....	Coarse to fine. Sandy.	Very fine. Smooth.
Slaking .....	Fast and complete.	Slow and complet
Water required to give paste.....	32%	38%
Plasticity .....	Lean.	Lean.
Air shrinkage .....	2	8
Fire shrinkage .....	4	4.5
Average tensile strength .....	6 lbs.	23
Maximum tensile strength .....	7 lbs.	24
Condition when burned .....	Porous.	Dense.
Color when burned .....	White.	White.
Incipient fusion .....	2300° F.	2350° F.
Vitrification (incomplete) .....	2500° F.	2550° F.
Viscosity .....	above 2700° F.	above 2700° F.

*Analysis of Kaolin, Springer pit, ½ mile N. E. of Webster.*

	No. 54.* Crude kaolin.	Insoluble residue.	No. 56. Washed kaolin.	Insoluble residue.
Moisture .....	.25	.....	2.05	.....
Silica .....	62.40	29.12	45.78	6.60
Alumina .....	26.51	3.85	36.46	.....
Ferric oxide .....	1.14	.65	.28	.....
Ferrous oxide .....	.....	.....	1.08	.....
Lime .....	.57	.....	.50	.....
Magnesia .....	.01	.....	.04	.....
Alkalies .....	.98	.90	.25	.....
Water (loss on ignition) ..	8.80	.....	13.40	.....
Total .....	100.66	34.52	99.84	.....
Fluxes .....	2.70	.....	2.15	.....
Specific gravity .....	2.58	.....	2.27	.....

*From the rational analysis we get the following:*

Clay substance .....	66.14	93.24
Quartz .....	15.61	6.60
Feldspar .....	18.91	

It is plain that the effect of the washing has been to eliminate the percentage of quartz and feldspar and relatively increase the clay substance nearly 30%. Of the fluxes only the alkalies have been decreased.

## KAOLIN IN MACON COUNTY.

NEAR WESTS MILL.—On the land of Geo. Brindel, near Wests Mill, is a deposit of kaolin of remarkable whiteness, which burns to

## \* Composition of Clay substance of 54:

Silica.....	50.50	Alumina.....	34.24	Ferric oxide ...	0.74
Lime.....	0.86	Magnesia.....	0.01	Alkalies .....	0.10
		Water .....	13.35		

pure white color, showing its excellent quality. It is very fine-grained, free from grit, and shows a few scattered white mica scales. It slakes slowly but thoroughly.

The addition of 31% of water gave a workable paste of the usual lean character. The bricks made from this paste shrunk 6% in drying and 6% in burning, giving a total shrinkage of 12%. The air-dried briquettes had an average tensile strength of 15 lbs. per square inch and a maximum of 18 lbs. Incipient fusion occurs at 2300° F., vitrification at 2600° F., and viscosity at over 2700° F. The clay burns to a pure white body.

The following analysis of the unwashed sample shows its remarkable purity:

*Analysis of Kuolin (No. 69) from Geo. Brindel's land, near Wests Mill.*

	Crude kaolin.	Insoluble residue.
Silica (total) .....	53.10	15.23
Alumina .....	33.06	0.07
Ferric oxide .....	1.18	0.46
Lime .....	0.38	....
Magnesia .....	0.08	....
Alkalies .....	0.83	0.80
Water (loss on ignition).....	11.32	....
Total .....	99.95	16.56
Total fluxes .....	2.47	
Specific gravity .....	2.31	

*From the above we get:*

Clay substance .....	83.39
Quartz .....	14.98
Feldspar .....	1.58

Subtracting the second column from the first, we get the composition of the clay substance, which, in the second of the two following columns, is recalculated to 100. The clay substance, it will be seen, is nearly pure kaolinite, but with a slightly greater amount of alumina in proportion to the silica than is called for by the formula of kaolinite:

*Composition of Clay Substance in Kuolin from Wests Mill.*

Silica .....	37.87	45.41
Alumina .....	32.99	39.56
Ferric oxide .....	0.72	0.86
Lime .....	0.38	0.45
Magnesia .....	0.08	0.09
Alkalies .....	0.03	0.03
Water (loss on ignition).....	11.32	13.58
	83.39	99.98

## KAOLIN IN MONTGOMERY COUNTY.

NEAR TROY.—Considerable quantities of kaolin have recently been discovered 4 miles west of Troy, Montgomery county.

From the various outcrops two samples were tested.

The first sample forwarded (No. 64) was a darker kaolin. This was a fine-grained, gritty clay, which passes almost entirely through a 60 mesh sieve. It slakes easily and quickly to fine grains.

The sample when washed yielded a residue of 40%, which is probably somewhat larger than would be obtained in actual practice, and the washed kaolin required 30% of water to produce a workable paste that was lean to the feeling. This paste shrunk 3% in drying and an additional 10% in burning, giving a total shrinkage of 13%. The average tensile strength of air-dried briquettes was 9 lbs. per square inch with a maximum of 12 lbs. per square inch. Incipient fusion occurred at 2100° F., vitrification at 2300° F., and viscosity at 2500° F.

The clay burns to a very pale buff.

The second sample forwarded was a white kaolin (No. 68) and does not possess the grayish tint which the other does. It shrank 3% in drying and 9% in burning, giving a total shrinkage of 12%. The air-dried briquettes had an average tensile strength of 10 lbs. per square inch with a maximum of 12 lbs. Incipient fusion occurs at 2100° F., vitrification at 2300° F., and viscosity at 2500° F. The kaolin burns to a deeper buff than the preceding one.

The coloration of these two kaolins is against their use for white ware, but they might be used for higher grades of stoneware, encaustic tiles, or in the body of refractory wares for laboratory use.

The crude white kaolin was at first tested, as its snow-white color suggested that it might burn white and to a dense body without further treatment. The results obtained were so similar to those of the washed white kaolin that they are simply given in the appended table. The tensile strength of the crude material was a few pounds greater and the shrinkage in burning three per cent. less.

An examination of the following analyses indicates the rather high iron percentage which accounts for the color of the burned clay. A comparison of the analysis of the washed and crude kaolin also points out that the percentage of sand has been reduced, but none of the iron removed.

In the following analyses No. 64a represents the darker kaolin (crude) from 4 miles west of Troy, No. 64 this darker kaolin washed, and No. 68 the white kaolin washed from the same locality.

*Analyses of Kaolin 4 miles W. of Troy, Montgomery Co.*

	No. 64a.	No. 64.	No. 68.
Moisture .....	.48	.53	.75
Silica .....	90.13	86.03	63.10
Alumina .....	4.99	6.46	23.33
Ferric oxide .....	1.86	2.14	2.97
Lime .....	.13	.17	.15
Magnesia .....	.01	.04	.09
Alkalies .....	1.03	1.00	1.90
Water (loss on ignition)....	1.93	2.90	7.65
Total .....	100.56	99.27	99.94
Insol. residue .....	85.85	78.54	41.08
Total fluxes .....	3.03	3.35	5.11
Specific gravity .....	2.47	2.32	2.34

*Analyses of insoluble residue from the above.*

	No. 64a.	No. 64.	No. 68.
Silica .....	84.64	77.25	38.25
Alumina .....	.20	.30	.85
Ferric oxide .....	.37	.28	.46
Alkalies .....	.64	.73	1.52
	85.85	78.54	41.08

From the above, by a rational analysis, we get the percentages of the mineral ingredients as follows:

*Mineral Composition of Kaolin 4 miles W. of Troy, N. C.*

	No. 64a.	No. 64.	No. 68.
Clay substance .....	14.71	20.83	58.92
Quartz .....	83.94	76.20	35.27
Feldspar .....	1.91	2.34	5.81

*Composition of the clay substance in the above.*

	No. 64a.	No. 64.
Silica .....	38.58	43.46
Alumina .....	33.66	30.04
Ferric oxide .....	10.46	9.30
Lime .....	.91	.84
Magnesia .....	.07	.19
Alkalies .....	2.70	1.33
Water (lost on ignition) ..	13.56	14.35
	99.94	99.51

## KAOLIN IN RICHMOND COUNTY.

NEAR BOSTICK.—Considerable residual kaolin has recently been found on the property of Robert W. Steele, near Bosticks Mills, 14 miles north of Rockingham, Richmond county. A number of test pits have been sunk and the exploitations indicate the presence of an

abundant amount of material. The deposit could be readily transported to market. It is two miles from the end of a lumber railroad, and after hauling to this point the lumber company would transport it to the railroad at Hoffman, a distance of 12 miles, for not exceeding 50 cents a ton; or this timber railroad could be extended easily and cheaply to the kaolin deposit.

The first point at which the kaolin appears is one mile south of Bostick P. O and near Christopher Bostick's cabin, where it crops out for a distance of fifty feet in a ditch by the roadside. It is next seen on the opposite side of the road, at base of hill, but between these two exposures is a red clay resulting from the decomposition of schistose rock.

Just east of the first-mentioned exposure, and in the woods about 100 feet from the road, a test pit four feet square has been sunk (No. 21). This showed  $1\frac{1}{2}$  feet overburden and then 3 feet kaolin. The pit had been sunk 10 feet through kaolin, but had caved in. About 30 feet from this another pit was sunk to a depth of 12 feet. This also shows the kaolin from one foot below the surface down to the bottom (No. 20). Several other small pits have been sunk within a radius of 75 feet, and all penetrated the kaolin. The material is fine-grained, with comparatively few angular fragments. There are scattered stains of iron, but these may disappear with depth.

Another series of pits (No. 22) have been sunk on Mr. Chapel's land, one mile due west of No. 21. These pits were sunk to a depth of 10 feet, and the kaolin appeared at 18 inches from the surface and continued to bottom of pits. This kaolin is whiter than that at 21. Between the two deposits there is a shallow valley, and it is not known whether 21 and 22 are portions of one vein or not.

Samples of Nos. 20, 21 and 22 were tested in their crude condition, and Nos. 20 and 22 were also washed.

No. 20 is a fine-grained kaolin with little coarse grit, which slakes slowly but completely to a fine-grained mass. It required 27.7% of water to give a workable paste, which shrank 4% in drying and 9% in burning. Incipient fusion occurs at  $2250^{\circ}$  F., vitrification at  $2500^{\circ}$  F. and viscosity at  $2700^{\circ}$  F. The average tensile strength of air-dried briquettes was 10 lbs. per square inch with a maximum of 14 lbs. per square inch. The clay burned to a dense body with slightly yellowish tint.

No. 21 slaked the same as 20. It required 26% of water to make workable but lean paste, which shrunk 3.5% in drying and 8% in burning. Incipient fusion occurred at  $2300^{\circ}$  F., vitrification at  $2500^{\circ}$  F. and viscosity at  $2700^{\circ}$  F. The clay burns to same tint as No. 20. Its average tensile strength was 13 lbs. per square inch, with a maximum of 16 lbs. per square inch.

No. 22 is a somewhat porous, fine-grained white clay with comparatively little grit, which slakes slowly but completely to fine grains.

It required 27.7% of water to make a workable but lean paste. This paste shrunk 4% in drying and an additional 8% in burning. The average tensile strength of the air-dried briquettes was 15 lbs. per square inch with a maximum of 16 lbs.

Incipient fusion occurs at 2250° F., vitrification at 2450° F., and viscosity at over 2700° F.

The following analyses of these three samples (crude kaolin) were made:

*Analyses of Kaolin near Bosticks Mills, 14 miles N. of Rockingham, Richmond Co.*

	Crude Kaolin.	No. 21. Insol. in H <sub>2</sub> SO <sub>4</sub> etc.	Crude Kaolin.	No. 20.* Insol. in H <sub>2</sub> SO <sub>4</sub> etc.	Crude Kaolin.	No. 22. Insol. in H <sub>2</sub> SO <sub>4</sub> etc.
Silica .....	68.15	47.45	70.63	48.10	73.70	62.33
Alumina .....	19.99	1.70	21.81	3.24	16.03	....
Ferric oxide .....	1.86	.20	1.49	.56	1.57	....
Lime .....	.13	....	.20	....	.38	....
Magnesia .....	.16	....	.29	....	.47	....
Alkalies .....	2.85	1.35	1.45	} Na <sub>2</sub> O .72 K <sub>2</sub> O .24 }	1.90	....
Moisture .....	.17	....	.08		....	....
Water (loss on ignition). ..	4.70	....	4.04	....	4.33	....
Total .....	98.01	50.70	99.99	52.86	98.38	62.33
Total fluxes .....	5.00	....	3.43	....	4.32	....
Specific gravity .....	2.52	....	2.41	....	2.43	....

From the above we obtain the mineralogical composition of the kaolins as being:

*Mineral composition of Kaolin near Bosticks Mills.*

	No. 21.	No. 20.	No. 22.
Clay substance .....	49.30	47.14	36.05
Feldspar .....	9.20	16.13	62.33
Quartz .....	41.50	36.73	

A 5-lb. sample of No. 20 was washed. The settlings amounted to 40%, which is probably somewhat larger than would be obtained in actual practice. The washed kaolin required 26% of water to give a workable paste that was lean but smooth. This paste shrunk 3% in

\*Composition of Clay Substance of No. 20:

Silica. ....	47.88
Alumina. ....	39.04
Ferric oxide .....	1.90
Lime .....	0.42
Magnesia .....	0.60
Alkalies .....	1.04
Water .....	8.58
	99.46

drying, and there was an additional shrinkage of 9% in burning. Incipient fusion occurred at 2250° F., vitrification at 2450° F., and viscosity at over 2700° F. There was a faint yellowish tint to the burned ware.

Sample No. 22 was also washed. The washed material was 35% of the original mass. It required 29% to give a lean but workable paste that shrunk 4% in drying and 7% in burning, giving a total shrinkage of 11%. The air-dried briquettes had an average tensile strength of 8 lbs. per square inch and a maximum of 11 lbs. Incipient fusion occurs at 2250° F., vitrification at 2450° F., and viscosity at over 2700° F. The clay when washed was pure white, but when burned had the faintest yellow tint.

An analysis was made of the washings from No. 20 and yielded the following percentages:

*Analysis of Washings from Kaolin (No. 20), near Bosticks Mills.*

	Total portion.	Insoluble portion.
Silica .....	71.12	44.38
Alumina .....	19.61	.15
Ferric oxide .....	2.18	.37
Lime .....	.17	....
Magnesia .....	.08	....
Alkalies .....	2.48	.77
Water (loss on ignition).....	4.33	....
Total .....	99.97	45.67

From the above we get the following:

*Mineral composition of washings from the Bostick Kaolin No. 20.*

Clay substance .....	54.30
Quartz .....	43.85
Feldspar .....	1.82

*Composition of clay substances from the Bostick Kaolin, sample No. 20.*

Silica .....	49.33
Alumina .....	35.90
Ferric oxide .....	3.15
Lime .....	.31
Magnesia .....	.14
Alkalies .....	3.15
Water (loss on ignition) .....	8.00
Total .....	99.98

**USES OF THE NORTH CAROLINA KAOLINS.**

The foregoing tests of the kaolins from several localities are to be looked upon as very promising, for they indicate the presence of much material of a high grade.



It would be possible to make comparisons of the North Carolina kaolins with those from other localities, but such comparisons have little practical value, unless the chemical and physical characters of each clay are known. Many ultimate and rational analyses of foreign kaolins have been published, but few physical tests are given.<sup>1</sup>

As a matter of interest, some of the North Carolina kaolins may be compared with celebrated foreign ones which are used in the manufacture of the highest grades of porcelain.

In the following columns the analyses, No. *a* (53) and No. *b*, are those of washed kaolin from the mine of the Harris Clay Co., the first analyzed by Chas. Baskerville, the second by C. Langenbeck.<sup>2</sup> Number *c* is an analysis of the well-known kaolin from Zettlitz, near Carlsbad, in Bohemia.

*Analyses of Kaolins: Webster, N. C. (a and b) and Zettlitz (c).*

	Nos. <i>a</i> (53).	No. <i>b</i> .	No. <i>c</i> .
Silica .....	45.70	45.80	46.82
Alumina .....	40.61	39.20	38.49
Water (loss on ignition) ....	8.98	13.11	12.86
Ferric oxide .....	1.39	.40	1.09
Lime .....	.45	.45	....
Magnesia .....	.09	.15	tr.
Alkalies .....	2.82	.92	1.40
	<hr/> 100.04	<hr/> 100.03	<hr/> 100.66

The washed white kaolin from 4 miles west of Troy, N. C. (No. 68), is interesting to compare with a German kaolin from Sennowitz, near Halle, (*d*) and which is used at Berlin for the manufacture of porcelain.<sup>3</sup> The two are very similar in their ultimate composition, but disagree strongly when their rational analyses are compared.

*Analyses of Kaolin from Troy, N. C. (68) and Sennowitz, Germany (d).*

	No. 68.	No. <i>d</i> .
Moisture .....	.75	....
Silica .....	63.10	64.87
Alumina .....	23.33	23.83
Water (loss on ignition).....	7.65	8.36
Ferric oxide .....	2.97	.83
Lime .....	.15	....
Magnesia .....	.09	.50
Alkalies .....	1.90	1.39
	<hr/> 99.94	<hr/> 99.78
Clay substance .....	58.92	63.77
Quartz .....	35.27	35.50
Feldspar .....	5.81	.73

<sup>1</sup> *Thonindustrie Zeitung*, 1893, p. 1811.

<sup>2</sup> *Chemistry of Pottery*.

<sup>3</sup> *Seg. Ges. Schr.*, p. 50.

The North Carolina kaolins, which contain under one per cent ferric oxide, are perfectly well adapted to the manufacture not only of white earthenware, but also of the best grades of porcelain. Those with  $1\frac{1}{2}$  to 2% of ferric oxide could no doubt be used for lower grades of white earthenware, while those containing 2 to  $2\frac{1}{2}$ % of ferric oxide might be utilized for mixing with fire-clays in the manufacture of refractory apparatus.

Kaolin containing very little grit, which would be the case when it had a very large percentage of clay substance, is eagerly sought and used by paper manufacturers. Kaolin is also used in the manufacture of ultramarine. For this purpose it should be as low in iron and lime as possible. An excess of silica is undesirable, but if too little is present it may be added in the form of finely powdered quartz.

## CHAPTER VI.

### POTTERY CLAYS IN NORTH CAROLINA.

#### THE POTTERY INDUSTRY.

The pottery industry of North Carolina has thus far been confined entirely to small potteries of perhaps 25,000 gallons annual capacity, whose trade is mostly local. There are between forty and fifty of these small potteries in the state, and most of them are located near Jugtown and Blackburn in Catawba county, and Henry in Lincoln county. There are others scattered over the state, as at Wilkesboro, Wilkes county, two miles north of Morganton, Burke county, and several other localities.

All of the potteries in Lincoln and Catawba counties obtain a large amount of their clay from the lowlands along the Clarke river (south fork of Catawba) two miles north of Lincolnton, some of them having to haul it 14 miles. They pay 50 cents a ton for it, and generally haul the clay on their return from a peddling trip, when their wagons would otherwise be empty.

The clays used for pottery purposes in North Carolina are the finer aluminous sediments underlying the river terraces to be found in many of the broader valleys, and the better ones are generally found near the shore line of the terrace. These terrace deposits of fine-grained, plastic clay are common, and with an increasing demand for pottery clays in the state, an abundance of the necessary material will probably be found close at hand.

In addition to the clay deposits underlying the terraces along Clarke river, especially north of Lincolnton, which have already been mentioned, the Catawba river, which flows by Morganton and Catawba, and thence southward past Mt. Holly, has also a marked terrace development; and the clays north of Morganton have already been used for pottery manufacture.

A third series of deposits of terrace clays is to be found along the Yadkin river.

Those at Wilkesboro emphasize the importance of making a rather thorough search for the proper kind of clay, for the material found there at one point is only suitable for brick, while one-quarter of a mile further it is eminently plastic, smooth, and burns to a dense hard body, just such as is needed for stoneware.

**REQUISITES OF A POTTERY CLAY.**

This term is meant to include the lower grades of earthenware and stoneware clay. For common earthenware, such as flower-pots, almost any red-burning, plastic clay will suffice, if it permits turning on the potter's wheel and burns to a good red but not vitrified body.

It is also possible to make a very serviceable grade of earthenware from calcareous clays, with up to 20 or 30 per cent. of calcium carbonate (provided it is finely divided and evenly distributed through the clay), and cover the ware with an easily fusible glaze of clay, clay and lead, or a mixture of fusible compounds. The majolica wares made in Italy and Germany are made from such clays.

Stoneware clays require a little more attention.

They should possess good plasticity in order to permit molding or turning without cracking.

Their tensile strength should be preferably not less than 125 lbs. or 150 lbs. per square inch.

They should not shrink excessively in burning, and should burn to a dense vitrified body at a temperature of 2000° F. or 2100° F. if possible. The lower temperature of vitrification is of course an important item of economy. For the same reasons the clay should permit of rapid drying. It should also be smooth and as free from grit as possible.

The fluxing impurities in a stoneware clay should be sufficiently high to produce a vitrified body. Iron is a desirable coloring ingredient. Lime, if in small amounts, 2-3%, is not very objectionable, but a large percentage may bleach the iron color, decrease the shrinkage and increase the fusibility. Calcium sulphate is undesirable, for its dissociation at high temperatures may cause blistering.

It is frequently found that better results can be obtained by mixing two different clays, the one furnishing stiffness and low shrinkage, the other plasticity and easier fusibility. This is done by all of the North Carolina potters, the two clays which they use being mixed in equal proportions, although in their case the chief difference of the clays used is in plasticity and stiffness.

Clays for making yellow ware are generally low grade fire-clays which burn to a buff color. They are usually washed to eliminate any coarse sand and pyrite nodules which they may contain. This is generally done in a circular vat or "blunger," in which there revolve stirrers, as mentioned under "The Preparation of Kaolin" (page 54).

Yellow ware is first molded and burned to incipient fusion, the transparent or opaque glaze applied and the ware burned again.

Some of the shale clays associated with the coal seams in North Carolina might answer for this purpose, but they have not yet been tested.

**STONEWARE MANUFACTURE.**

The methods at present employed within the State are somewhat crude, but best adapted, perhaps, to the size of the plant and available capital.

The clay is mixed in a vertical box, in which there is set a shaft with iron cross-pieces. This shaft is turned by horse-power, and the clay becomes mixed by the action of the iron arms. Before molding, the clay is further wedged. It is tempered to quite a soft paste, whose total shrinkage in drying and burning is 20-25%, according to the potters. The molding is done on the old-fashioned "kick-wheel," and the green ware dried on shelves set over a long, low, hot-air flue in the centre of the room.

The wares are burned in a long, low kiln resembling a muffle in form. The glaze is either old glass or furnace slag ground fine and applied in the form of a slip. The glass is put on the wares set in the upper end of the kiln, as it melts easier, while the ware set in the lower end of the kiln is coated with the ground slag.

If a pottery clay possesses all the requisite chemical and physical characters but is gritty, it is often possible to remove the grit by washing. This is best done in a circular tub in which there revolve stirring arms, as mentioned under the head of kaolin washing. The water, with suspended clay, is drawn off and the latter allowed to settle in tanks. The clear water is then drawn off and the clay can be dried by steam or in the sun. Sandy clays will dry quicker, but they do not burn to as dense a body.

None of the North Carolina potters use Albany slip for glazing their ware. If they did the product would be far more sightly than it is now. The crude glaze which they use is cheap, but it cracks very soon. With a little experimenting of the proper nature it would be possible to find glazes adaptable to the clays now being used. This, together with the application of improved methods and some care, would enable the North Carolina potter to put a far better grade of ware on the market, and sell it at a correspondingly increased price. At present nearly all of the earthenware and stoneware used in the larger towns and cities of North Carolina comes from other states.

The molding is all done by hand, and in the present state of the industry plaster molds have not been deemed necessary.

As has been already stated, many of these river clays are well adapted to stoneware manufacture, and would give a far better product than is now being made. Their temperature of vitrification is also high enough to bear the application of Albany slip as a glazing material.

The Albany slip is an impure fusible clay found in the Hudson river valley in New York state. It vitrifies at 1800° F. and forms a brown,

evenly colored coat. No other clay has yet been found which has these qualities of such constancy.

In larger stoneware factories the kick-wheel is found insufficient. For the ordinary symmetrical shapes a common potter's wheel can be used, operated by steam power. Crocks, jugs and similar articles are molded on this, the potter throwing a lump of clay on the revolving wheel and then deftly working it up into the desired form simply by using his fingers.



FIG. 2.—THE POTTERS' JOLLY WHEEL, No. 3.

Many articles are molded on a jolly wheel. With this a plaster or Paris mold is used to form the article. The mold is set on the wheel and, while being revolved, a lump of the tempered clay is thrown into it and worked out in a thin layer over the interior surface of the mold.

The mold is then set aside to dry, and the clay shrinks from the mold and hardens sufficiently to be lifted out. Fig. 2 shows a jolly made by the Turner, Vaughn & Taylor Co., of Cuyahoga Falls, Ohio.

The speed of drying depends on the clay. If possible, the drying is done in a steam-heated room for a number of hours until the ware is dry enough to be burned. If slip glaze is used the ware has to be first dipped into it and once more dried before burning, but if salt glaze is used the ware is put directly in the kiln.

The quicker the drying and burning which a clay will permit without cracking the more economical it is to use it.

Very plastic clays have to be dried slowly to prevent cracking, but this difficulty may be overcome by the admixture of more sandy ones.

Burning may be done in circular kilns, which are either up-draft or down-draft in their action. The burning and cooling take from 5-8 days, depending on the clay.

The water-smoking can generally be carried on rapidly, but the cooling should not be hurried, to avoid cracking.

#### POTTERY INDUSTRY IN BURKE COUNTY.

**NEAR MORGANTON.**—Three miles north of Morganton is the North Carolina pottery, at present inoperative, but the plant is one of the largest in the State. The clay which it is claimed was alone used is on Manly McDowell's property,  $1\frac{1}{2}$  miles west of Morganton and along the road, an eighth of a mile from the Catawba river.

This clay (No. 51) directly underlies the terrace surface and is a fine-grained, gritty, soft clay, overlain by 18 inches to 2 feet of yellow loam. The bed of clay is 6-7 feet thick.

The addition of 36% of water gave a stiff, somewhat smooth, but rather lean mass, which shrunk 9.6% in drying and 4.5% in burning, giving a total shrinkage of 14.1%.

The air-dried briquettes of this clay had an average tensile strength of 60 lbs. per square inch with a maximum of 81 lbs.

Incipient fusion occurs at 1950° F., vitrification at 2100° F., and viscosity at 2250° F. The clay burns red.

The analysis of the clay is as follows:

#### *Analysis of Pottery Clay (No. 51), Manly McDowell's, near Morganton.*

Moisture .....	1.68
Silica (total) .....	69.58
Alumina .....	14.03
Ferric oxide .....	6.41
Lime .....	.40
Magnesia .....	.27
Alkalies .....	1.65

## CLAY DEPOSITS IN NORTH CAROLINA.

Water (loss on ignition) .....	5.73
Total .....	99.75
Clay substance .....	45.47
Free sand .....	54.28
Total fluxes .....	8.73
Specific gravity .....	2.59

It is manifestly impossible that pottery could have been made of this clay alone, on account of its low binding power, and a more plastic material must have been mixed with it.

## POTTERY INDUSTRY IN CATAWBA COUNTY.

NEAR BLACKBURN.—Many of the potters, especially those at Blackburn, use a highly plastic, dark-colored clay obtained two miles west of Blackburn on the property of M. Finger. This clay is soft and dense, and slakes slowly to irregular, scaly flakes. There is a not inconsiderable amount of organic matter present in it.

The addition of 30% of water was required to give a workable paste which was very plastic. This paste shrunk 12% in drying and an additional 7% in burning, giving a total shrinkage of 19%. The brick made from this clay had when air-dried an average tensile strength of 148 lbs. per square inch and a maximum of 200 lbs. Incipient vitrification occurred at 1950° F., vitrification at 2100° F., and viscosity at 2200° F.

The clay burns to a grayish brown body of good density.

The analysis of the clay is as follows:

*Analysis of Pottery Clay (No. 50), 2 miles N. W. of Blackburn.*

Moisture .....	2.08
Silica (total) .....	50.17
Alumina .....	28.77
Ferric oxide .....	2.88
Lime .....	.05
Magnesia .....	.22
Alkalies .....	1.04
Water (loss on ignition) .....	14.03
Total .....	99.24
Clay substance .....	73.19
Free sand .....	26.05
Total fluxes .....	4.19
Specific gravity .....	2.35

The high percentage of loss on ignition is due to the several per cent of organic matter in the clay. This also increases the plasticity and adds somewhat to the air shrinkage.



## POTTERY INDUSTRY IN LINCOLN COUNTY.

NEAR LINCOLNTON.—The clay along the Clarke river, northwest and north of Lincolnton, supplies nearly fifty potters in Catawba and Lincoln counties.

The material is a fine-grained gray clay with occasional yellow iron stains. Two samples were tested, No. 61 from the pits at end of lane on T. Rhodes' property two miles northwest of Lincolnton, and No. 49 from about one-quarter mile farther up the river.

No. 61 is a fine, gritty clay with scattered mica scales. It slakes slowly. The addition of 35% of water gave a smooth, very plastic mass which shrunk 10% in drying and 7% in burning, giving a total shrinkage of 17%. The air-dried briquettes of this clay had an average tensile strength of 157 lbs. per square inch and a maximum of 186 lbs.

Incipient fusion occurs at 1900° F., vitrification at 2100° F., and viscosity at 2300° F.

The clay burns to a dark red body.

This clay is not as plastic as that obtained northwest of Blackburn, nor is its tensile strength always so great, as will be seen from the tests of the next sample, but it is a good material for common stoneware.

The analysis of the clay is as follows:

*Analysis of Pottery Clay (No. 61), T. Rhodes' land, 2 miles N. W. of Lincolnton.*

Moisture .....	2.10
Silica (total) .....	57.20
Alumina .....	24.82
Ferric oxide .....	3.25
Ferrous oxide .....	1.42
Lime .....	.73
Magnesia .....	.13
Alkalies .....	.93
Water (loss on ignition) .....	8.25
<hr/>	
Total .....	98.83
Clay substance .....	62.27
Free sand .....	36.57
Total fluxes .....	6.46
Specific gravity .....	2.51

Sample No. 49 from the pits on T. Rhodes' property is finely gritty clay which slakes slowly but completely. It required the addition of 40% of water to make a workable paste, which was very plastic to the feel. This paste shrunk 9.5% in drying and 5.5% in burning, giving a total shrinkage of 15%. The air-dried briquettes made from this mud had an average tensile strength of 133 lbs. per square inch and a maximum of 158 lbs.

Incipient fusion occurred at 1900° F., vitrification at 2100° F. viscosity at 2300° F.

The clay burns reddish white at 1900° F. and deep red at 2100° F.

The composition of it is as follows:

*Analysis of Pottery Clay (No. 49), Rhodes' land, 2½ miles N. W. of Lincolnton.*

Moisture .....	.69
Silica (total) .....	57.08
Alumina .....	26.11
Ferric oxide .....	4.64
Lime .....	.20
Magnesia .....	.16
Alkalies .....	1.42
Water (loss on ignition) .....	8.52
Total .....	98.82
Clay substance .....	62.76
Free sand .....	35.96
Total fluxes .....	6.42
Specific gravity .....	2.53

POTTERY INDUSTRY IN WILKES COUNTY.

NEAR WILKESBORO.—At the west end of the village of Wilkesboro a small pottery has used the clay outcropping at the fork of the road and also drawn upon an additional bed in a field to the north.

That dug along the road is a light bluish-white clay, tough, and containing small amounts of fine grit. This is used to furnish stiff the potter's mixture, while that from the field across the road furnishes bond in burning.

The stiff clay (No. 34) is fine-grained and contains little mica. It slaked slowly and required the addition of 40% of water to make a workable paste, which was slightly plastic. This shrunk 7.5% in drying and 12% in burning, giving a total shrinkage of 19.5%. The dried briquettes had an average tensile strength of 51 lbs. per square inch and a maximum tensile strength of 63 lbs. per square inch.

Incipient fusion occurred at 1900° F., vitrification at 2050° F. viscosity at 2200° F. The clay burns red and dense. Its composition is as follows:

*Analysis of Pottery Clay (No. 34), near Wilkesboro.*

Moisture .....	1.28
Silica (total) .....	54.38
Alumina .....	27.27
Ferric oxide .....	5.48
Lime .....	.45
Magnesia .....	.41

A good fire-brick is sometimes made by mixing a non-plastic refractory clay with a very plastic, dense burning semi-refractory one.

Fire-brick are now mostly molded by hand and repressed. For a time many manufacturers molded their bricks in stiff mud or even dry-press machines, but most of them have returned to the old method.

#### FIRE-CLAYS IN CLEVELAND COUNTY.

**NEAR GROVER.**—Surrounding the village of Grover is an extensive series of outcrops of a light bluish-gray sandy clay of variable depth and nature. In some pits it shows its residual character beyond a doubt, but at other points, if of residual origin, it appears to have been sorted over and compacted by water action. Two companies have mined this clay, the Grover Brick Company and the Powhatan Clay Manufacturing Company of Richmond, Va.

The former company has one pit in a hollow along a stream three quarters of a mile due S. W. of Grover station. The upper three feet are loam with lumps of red clay, and under this come 6 feet of bluish-white sandy clay (No. 43). The Grover Brick Company make their white fire-brick from this.

A sample of this (No. 43) shows it to be a gritty, fine to coarse, dense, tough clay, with abundant coarse quartz grains. It slakes slowly to irregular grains and scales.

The addition of 32% of water gave a workable mass of moderate plasticity. This paste shrunk 10.6% in drying and 6% in burning, giving a total shrinkage of 16.6%. The average tensile strength of the air-dried briquettes was 38 lbs. per square inch with a maximum of 42 lbs.

Incipient fusion occurs at 2100° F., vitrification at 2300° F., and viscosity at 2500° F. The clay burns white at incipient fusion, but light buff at higher temperature.

The white-burned brick made from this clay are sold as fire-brick. The composition of the clay is as follows:

#### *Analysis of Fire-clay (No. 43), Grover Brick Co.'s Eskridge pit.*

Moisture .....	.76
Silica (total) .....	68.28
Alumina .....	18.83
Titanium oxide .....	.27
Ferric oxide .....	2.60
Lime .....	.70
Magnesia .....	.13
Alkalies .....	2.29
Water (loss on ignition) .....	6.47
Total .....	100.33

## CHAPTER VII.

### FIRE-CLAYS AND PIPE-CLAYS IN NORTH CAROLINA.

#### FIRE-CLAYS.

The fire-clay deposits of North Carolina are few in number as thus far known. They are either residual deposits or the wash from them. There are a number of siliceous clays in the State which at a moderate temperature burn to a cream-white or white color, and the bricks made from these clays are used for bakers' ovens and boiler foundations. They are called fire-brick, but are not such in the true sense of the word.

Refractory clays occur at Pomona, Guilford county, and Grover, Cleveland county, and are mined at both places.

While it is desirable that fire-clays should possess good plasticity and low shrinkage, the main point is the refractory character. A good fire-clay should be unaffected by 2500° F., but many good clays will not stand this degree of heat, nor is it required for the uses to which they are to be put. In general, it may be said that the fusible impurities of a fire-clay should not exceed  $3\frac{1}{2}$  or 4 per cent. if it is fine-grained, or even less if it is very fine-grained, but if coarse-grained they may reach even 5%. The clay on the railroad near Spout Springs, for example, has only 3.81% of total fluxes, yet on account of its very fine grain it is by no means refractory. If a fire-clay shrinks too much in burning this may be often counteracted by the addition of "grog," viz., sand, ground fire-brick or other substances which would dilute the shrinkage. Fire-clays which are fat and plastic generally burn to a dense body, but crack considerably owing to their high shrinkage. This may be counteracted best by mixing burned clay of the same or some other kind with the fresh material. This burned clay or grog should be burned as dense as possible before use. Fine-grained or powdered grog permits the brick to shrink more in burning than coarse-grained, and bricks with the latter generally stand changes of temperature better. Next to burned clay, quartz is the most important grog.

If a fire-brick made only of clay and clay-grog still shrinks when placed in the furnace, sharp quartz grains should be added, as they have a tendency to expand on repeated heatings. Fine-grained quartz sand should in no case be added as it tends to act as a flux in burning. The addition of coarse quartz must also be within limits, for if too large it loosens the stone by expansion.

A good fire-brick is sometimes made by mixing a non-plastic refractory clay with a very plastic, dense burning semi-refractory one.

Fire-brick are now mostly molded by hand and repressed. For a time many manufacturers molded their bricks in stiff mud or even dry-press machines, but most of them have returned to the old method.

#### FIRE-CLAYS IN CLEVELAND COUNTY.

**NEAR GROVER.**—Surrounding the village of Grover is an extensive series of outcrops of a light bluish-gray sandy clay of variable depth and nature. In some pits it shows its residual character beyond a doubt, but at other points, if of residual origin, it appears to have been sorted over and compacted by water action. Two companies have mined this clay, the Grover Brick Company and the Powhatan Clay Manufacturing Company of Richmond, Va.

The former company has one pit in a hollow along a stream three quarters of a mile due S. W. of Grover station. The upper three feet are loam with lumps of red clay, and under this come 6 feet of bluish-white sandy clay (No. 43). The Grover Brick Company make their white fire-brick from this.

A sample of this (No. 43) shows it to be a gritty, fine to coarse, dense, tough clay, with abundant coarse quartz grains. It slakes slowly to irregular grains and scales.

The addition of 32% of water gave a workable mass of moderate plasticity. This paste shrunk 10.6% in drying and 6% in burning, giving a total shrinkage of 16.6%. The average tensile strength of the air-dried briquettes was 38 lbs. per square inch with a maximum of 42 lbs.

Incipient fusion occurs at 2100° F., vitrification at 2300° F., and viscosity at 2500° F. The clay burns white at incipient fusion, but light buff at higher temperature.

The white-burned brick made from this clay are sold as fire-brick. The composition of the clay is as follows:

#### *Analysis of Fire-clay (No. 43), Grover Brick Co.'s Eskridge pit.*

Moisture .....	.76
Silica (total) .....	68.28
Alumina .....	18.83
Titanium oxide .....	.27
Ferric oxide .....	2.60
Lime .....	.70
Magnesia .....	.13
Alkalies .....	2.29
Water (loss on ignition) .....	6.47
<b>Total .....</b>	<b>100.33</b>

east of the company's new factory. The available portion of it is three feet thick, for it then changes into a very sandy clay which possesses exceedingly low plasticity. The upper clay slakes very slowly to a granular, gritty mass. It required 26% of water to make a workable paste out of it, and this was lean. This paste shrunk 10% in drying and 2% additional in burning, giving a total shrinkage of 12%. Air-dried briquettes made from this paste had an average tensile strength of 47 lbs. per square inch and a maximum of 49 lbs. per square inch.

Incipient fusion occurs at 2150° F., vitrification at 2350° F., and viscosity at 2550° F.

The clay burns red or buff, depending on the intensity of firing and oxidizing condition of the fire. Its chemical composition is as follows:

*Analysis of Fire-clay (No. 25), Pomona Terracotta Works.*

Moisture .....	.98
Silica (total) .....	70.45
Alumina .....	17.34
Ferric oxide .....	3.16
Ferrous oxide .....	.33
Lime .....	.25
Magnesia .....	.22
Alkalies .....	.70
Water (loss on ignition) .....	6.63
Total .....	100.06
Clay substance .....	48.26
Free sand .....	51.50
Fluxes .....	4.66
Specific gravity .....	2.55

The under clay (25a) is a very siliceous white clay that slakes slowly and completely to irregular grains.

Thirty-three per cent. of water added to it gave a workable but very lean mass which shrunk 3% in drying and 3% in burning, giving a total shrinkage of 6%.

The average tensile strength of air-dried briquettes was 14 lbs. per square inch with a maximum of 16 lbs. Incipient fusion occurred at 2200° F., vitrification at 2400° F., and viscosity at 2600° F. The clay burns to a gray buff.

This clay is not used. Attempts have been made to mix it with the sewer-pipe clay, but it would not take the salt glaze. The trouble is probably similar to a case which Prof. E. Orton, Jr., cited to the writer from Ohio, the difficulty lying in the extremely siliceous nature of the clay, which does not possess enough alumina to unite with the silica and salt to give the glaze, which is a silicate of aluminium and sodium.

The composition of this under fire clay is as follows:

*Analysis of Clay (No. 25a), under the Fire-clay, Pomona Terracotta Works.*

Moisture .....	1.17
Silica (total) .....	70.15
Alumina .....	15.51
Ferric oxide .....	3.34
Lime .....	.83
Magnesia .....	.07
Alkalies .....	3.75
Water (loss on ignition) .....	5.14
Total .....	99.96
Clay substance .....	39.46
Free sand .....	60.50
Total fluxes .....	7.99

There is probably much undecomposed feldspar in the clay, and while the total fluxes are high, the grain is so coarse as to raise the fusing point.

WOODROFFE CLAY BANK.—Thos. Woodroffe, of Greensboro, has a similar deposit of fire-clay about one mile north of the Pomona sewer-pipe works and along the same creek. It is likewise a very gritty, tough, dense, light gray clay, that slakes very slowly. Twenty-eight per cent. of water was required to make a workable mixture. This shrunk 9.3% in drying and 4% in burning, giving a total shrinkage of 13.3%. Air-dried briquettes of the mud had an average tensile strength of 51 lbs. per square inch and a maximum of 56 lbs. per square inch. Incipient fusion occurs at 2100° F., vitrification at 2300° F., and viscosity at 2500° F.

If burned reddish when heated to barely 2100° F., or in reducing fire the clay remained white. This is the condition of the bricks manufactured from this fire-clay at Pomona, but if the clay is raised above 2100° F. and with an oxidizing fire the clay burns buff or red.

The composition of the clay from Woodroffe's bank is shown by the following:

*Analysis of Fire-clay (No. 29), Woodroffe Bank.*

Moisture .....	1.43
Silica (total) .....	71.60
Alumina .....	15.27
Ferric oxide .....	3.33
Lime .....	.17
Magnesia .....	.21
Alkalies .....	2.12
Water (loss on ignition) .....	5.40
Total .....	99.53
Clay substance .....	42.83
Free sand .....	56.70
Total fluxes .....	5.83
Specific gravity .....	2.60

This closely approaches the Pomona Sewer-pipe and Brick Co.'s cl in composition.

#### PIPE-CLAYS IN NORTH CAROLINA.

Clays which are suitable for the manufacture of sewer-pipe should answer the following requirements:

They should be plastic to permit molding without cracking; they should have a tensile strength of 125-150 lbs. The clay should burn to a dense, hard, impervious body, of a red or deep red color. The drying should permit of rapidity, and the ware should not warp or crack in doing so. The same may be said of the burning.

An excess of fluxing impurities may render a clay so fusible that burning it softens to such an extent as to lose its shape. It is a very common practice therefore to use a mixture of clays, the one fusible to form a bond in burning, the other much less so to preserve the shape of the ware. This is done at Pomona, for example.

There should be a considerable but not excessive percentage of silica in the clay for the salt vapors to unite with and form the glaze. An excess of silica is detrimental, however, to the formation of a good glaze, for the latter is a silicate of sodium and aluminium, and consequently if there is an excess of silica and lack of alumina, a poor glaze or perhaps none at all, may form. This is probably the case with the under fire-clay at Pomona, which for a while was mixed in with the pipe-clay.

#### MANUFACTURE OF SEWER-PIPE AND TILE.

If shale or hard clay is used it has to be first ground in a dry pugmill but with soft clays they can be put directly into the wet pan or chamfer mill, which in a few minutes tempers each charge rapidly and thoroughly. (Plate VI, fig. 2.)

This method of tempering is far more thorough and quicker than the pugmill, although requiring more power.

The tempered clay is generally taken to the upper story of the factory by means of bucket elevators and discharged into the clay cylinder of the sewer-pipe press. (Fig. 3, p. 87, and Plate VI, fig. 1.)

The press (fig. 3, page 87) consists of two cylinders, an upper steam cylinder and a lower clay cylinder, and the ratio of their diameters is generally as 3 : 1. The clay cylinder is filled with clay, and the piston then forced downwards by the piston of the steam cylinder above, the pistons of the two being continuous. This forces the clay out through the die at the bottom. When the clay in the form of a pipe has issued to the proper distance, the machine is stopped. If of small diameter the pipe is sometimes simply broken off, but for large pipe and usually small ones the pipe is cut off close to the mouth of the die either by means of a wire or else by an automatic knife edge located within the die.



*Analysis of Clay (No. 25a), under the Fire-clay, Pomona Terracotta Works.*

Moisture .....	1.17
Silica (total) .....	70.15
Alumina .....	15.51
Ferric oxide .....	3.34
Lime .....	.83
Magnesia .....	.07
Alkalies .....	3.75
Water (loss on ignition) .....	5.14
Total .....	<u>99.96</u>
Clay substance .....	39.46
Free sand .....	60.50
Total fluxes .....	7.99

There is probably much undecomposed feldspar in the clay, and while the total fluxes are high, the grain is so coarse as to raise the fusing point.

WOODROFFE CLAY BANK.—Thos. Woodroffe, of Greensboro, has a similar deposit of fire-clay about one mile north of the Pomona sewerage works and along the same creek. It is likewise a very gritty, tough, dense, light gray clay, that slakes very slowly. Twenty-eight per cent. water was required to make a workable mixture. This shrunk 9.3% on drying and 4% in burning, giving a total shrinkage of 13.3%. Air-dried briquettes of the mud had an average tensile strength of 51 lbs. per square inch and a maximum of 56 lbs. per square inch. Incipient fusion occurs at 2100° F., vitrification at 2300° F., and viscosity at 2600° F.

If burned reddish when heated to barely 2100° F., or in reducing fire the clay remained white. This is the condition of the bricks manufactured from this fire-clay at Pomona, but if the clay is raised above 2100° F. and with an oxidizing fire the clay burns buff or red.

The composition of the clay from Woodroffe's bank is shown by the following:

*Analysis of Fire-clay (No. 29), Woodroffe Bank.*

Moisture .....	1.43
Silica (total) .....	71.60
Alumina .....	15.27
Ferric oxide .....	3.33
Lime .....	.17
Magnesia .....	.21
Alkalies .....	2.12
Water (loss on ignition) .....	5.40
Total .....	<u>99.53</u>
Clay substance .....	42.83
Free sand .....	56.70
Total fluxes .....	5.83
Specific gravity .....	2.60

This closely approaches the Pomona Sewer-pipe and Brick Co.'s clay in composition.

#### PIPE-CLAYS IN NORTH CAROLINA.

Clays which are suitable for the manufacture of sewer-pipe should answer the following requirements:

They should be plastic to permit molding without cracking; they should have a tensile strength of 125-150 lbs. The clay should burn to a dense, hard, impervious body, of a red or deep red color. The drying should permit of rapidity, and the ware should not warp or crack in doing so. The same may be said of the burning.

An excess of fluxing impurities may render a clay so fusible that in burning it softens to such an extent as to lose its shape. It is a very common practice therefore to use a mixture of clays, the one fusible to form a bond in burning, the other much less so to preserve the shape of the ware. This is done at Pomona, for example.

There should be a considerable but not excessive percentage of silica in the clay for the salt vapors to unite with and form the glaze. An excess of silica is detrimental, however, to the formation of a good glaze, for the latter is a silicate of sodium and aluminium, and consequently if there is an excess of silica and lack of alumina, a poor glaze or perhaps none at all, may form. This is probably the case with the under fire-clay at Pomona, which for a while was mixed in with the pipe-clay.

#### MANUFACTURE OF SEWER-PIPE AND TILE.

If shale or hard clay is used it has to be first ground in a dry pan, but with soft clays they can be put directly into the wet pan or chaser mill, which in a few minutes tempers each charge rapidly and thoroughly. (Plate VI, fig. 2.)

This method of tempering is far more thorough and quicker than a pugmill, although requiring more power.

The tempered clay is generally taken to the upper story of the factory by means of bucket elevators and discharged into the clay cylinder of the sewer-pipe press. (Fig. 3, p. 87, and Plate VI, fig. 1.)

The press (fig. 3, page 87) consists of two cylinders, an upper steam and a lower clay cylinder, and the ratio of their diameters is generally as 3 : 1. The clay cylinder is filled with clay, and the piston then forced downwards by the piston of the steam cylinder above, the piston rods of the two being continuous. This forces the clay out through the die at the bottom. When the clay in the form of a pipe has issued to the proper distance, the machine is stopped. If of small diameter the pipe is sometimes simply broken off, but for large pipe and usually small ones the pipe is cut off close to the mouth of the die either by means of a wire or else by an automatic knife edge located within the die.



FIG. 1.—PRESS FOR SEWER-PIPE, TILE, AND HOLLOW BRICK.



FIG. 2.—CHASER MILL FOR TEMPERING CLAY FOR SEWER-PIPE.



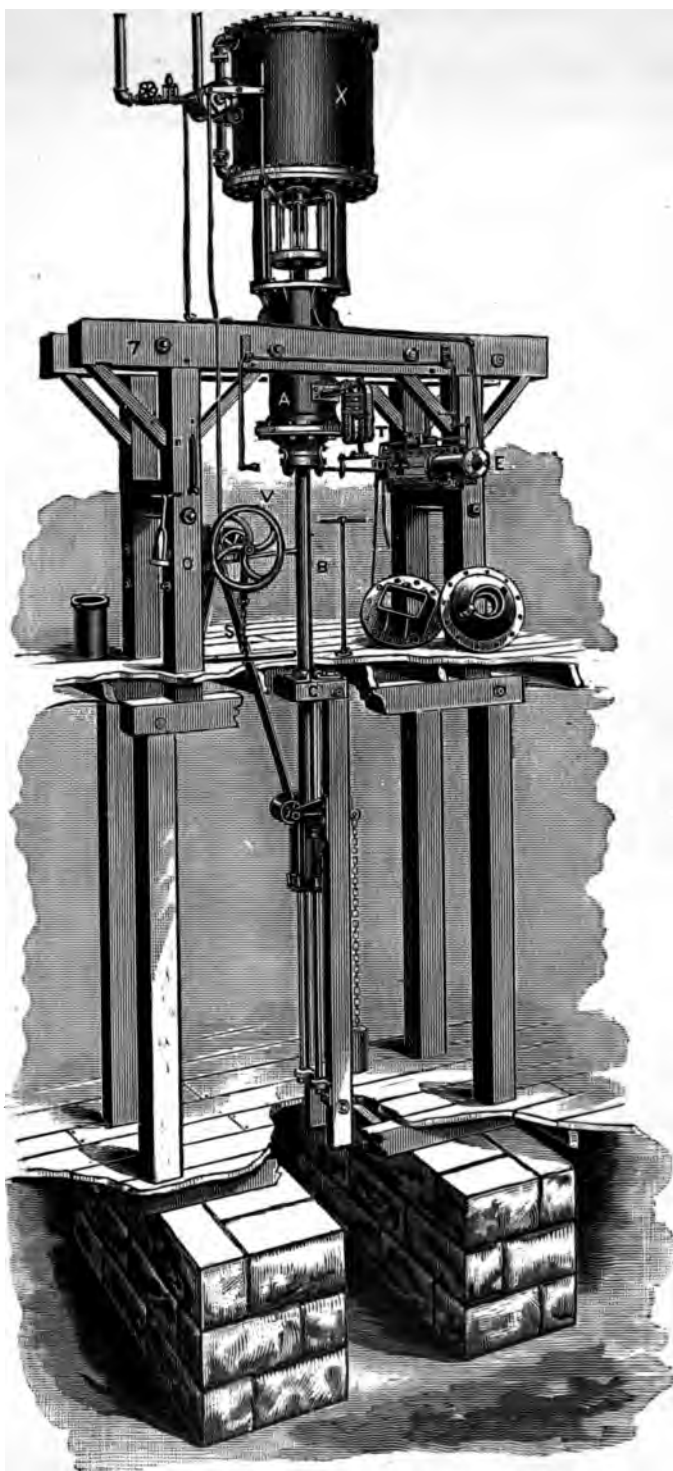


FIG. 3.--VAUGHN SEWER-PIPE PRESS, No. 7.  
60 inch Steam Cylinder, 36 inch Clay Cylinder.

The edges of the pipe are trimmed and the pipe are then set on drying floor.

Small diameter pipe can be dried comparatively fast, but large must be dried very slowly.

Sewer-pipe are usually burned in circular kilns of down-draft tern, which are from 16-25 ft. (rarely more) in diameter. The are set on top of each other, and when there are several sizes the nested. Figure 1 of Plate VII shows a circular down-draft kiln.

The burning can proceed quite rapidly on account of the thin of the ware. The salt is added to the fires when the temperature the kiln has reached its maximum.

Sewer-pipe should be free from blister, cracks and other defects. They should also be straight.

Elbows and Y's are made by molding the clay in plaster molds. In the case of Y's and T's straight pieces of pipe are sometimes joined to fit together in the desired shape, and the parts cemented by. They have to be dried more slowly. Sewer-pipe are made from 2½ ft. in length, and in diameter from 3-30 inches.

#### GUILFORD COUNTY.

POMONA TERRACOTTA Co.'s WORKS.—The Pomona Terracotta company has its works and clay pits at Pomona, three miles west of Guilfordboro. The clays occur in the bottom of the flat valley along both sides of North Buffalo creek, and are practically of two kinds, a plastic clay, and a white quartzose clay, called a fire-clay. The pipe-clay is said to occur only on the north side of the creek and the fire-clay on the south side. This is true for the sewer-pipe company's pits, and they also claim it to hold true at other points above and below them on the creek. There are four pits opened up in the pipe-clay. In the one or that nearest to the factory, there are five feet of dark clay, and one foot of red. The material from this pit furnishes one-half of the sewer-pipe mixture. That in the second pit is similar to the lower clay in the first, but is said to shrink less in burning.

The upper red in the first pit (No. 27) is a lean, gritty clay, and requires the addition of 30% of water to make a workable paste. In water the clay slakes quickly to scaly fragments. The clay shrinks 10% in drying and 6% in burning, giving a total shrinkage of 16%. The average tensile strength of the air-dried briquettes was 59 lbs. per square inch, with a maximum of 67 lbs. per square inch. Incipient fusion occurs at 2000° F., vitrification at 2150° F., and viscosity at 2300° F. The clay burns to a brownish red. Its composition is as follows:



FIG. 1.—CIRCULAR DOWN-DRAFT KILN FOR TILE, &c.



FIG. 2.—TUNNEL DRYERS USED IN BRICK MAKING.  
(See page 98.)





*Analysis of upper Pipe-clay (No. 27), Pomona Terracotta Co.*

Moisture .....	2.05
Silica (total) .....	54.28
Alumina .....	22.27
Ferric oxide .....	8.45
Ferrous oxide .....	1.33
Lime .....	.45
Magnesia .....	.18
Alkalies .....	.60
Water (loss on ignition) .....	10.50
Total .....	100.11
Clay substance .....	67.57
Free sand .....	32.51
Fluxes .....	11.01
Specific gravity .....	2.50

The color of the fresh clay is evidently due to the high amount of hydrated ferric oxide or limonite.

The under clay (No. 26) from this same pit is also a gritty clay, but more plastic. It slakes slowly to scaly fragments. Forty per cent. of water was required to make a workable mass, which shrunk 10% in drying and 6% in burning, giving a total shrinkage of 16%. The air-dried briquettes made from this material had an average tensile strength 86 lbs. per square inch and a maximum of 103 lbs. Incipient fusion occurred at 2050° F., vitrification at 2250° F., and viscosity at 2450° F. The clay burns red. Its composition is shown by the following analysis:

*Analysis of under Pipe-clay (No. 26), Pomona Terracotta Co.*

Moisture .....	1.53
Silica (total) .....	58.73
Alumina .....	23.94
Ferric oxide .....	3.71
Lime .....	.05
Magnesia .....	.09
Alkalies .....	1.25
Water (loss on ignition) .....	9.80
Total .....	99.10
Clay substance .....	65.70
Free sand .....	33.40
Fluxes .....	5.10
Specific gravity .....	2.52

The clay in the second pit (No. 28) is a gray, gritty clay with numerous quartz grains, tough, moderately fine-grained, and slakes slowly to angular granules.

It required the addition of 33% of water to produce a workable mass, which, however, was quite plastic, but did not feel as plastic as the tensile strength would suggest it to be. This mixture shrunk 8% in drying and 3% in burning. The average tensile strength of the air-dried briquettes was 145 lbs. per square inch, with a maximum of 160 lbs. per square inch. Incipient fusion occurred at 2000° F., vitrification at 2200° F., and viscosity at 2400° F.

The clay analyzed as follows:

*Analysis of Pipe-clay (No. 28), 2nd pit Pomona Terracotta Co.*

Moisture .....	2.20
Silica (total) .....	70.75
Alumina .....	13.87
Ferric oxide .....	5.01
Lime .....	.82
Magnesia .....	.29
Alkalies .....	1.15
Water (loss on ignition) .....	5.00
<b>Total .....</b>	<b>99.09</b>
Clay substance .....	39.40
Free sand .....	59.70
Fluxes .....	7.27
Specific gravity .....	2.51

As these three clays serve different purposes in the manufacture the sewer-pipe, it may be well to compare them.

No. 26. Good plasticity.

No. 27. Gives a better red in burning, and vitrifies at lower temperature.

No. 28. Shrinks less and has better bonding qualities. The characters are summed up in the following table:

*Comparison of Pipe-clays, Pomona Terracotta Co.*

No. of the Sample.	Feel.	Shrinkage.		Tensile Strength.		Fluxes.	Temperature in F. Deg.		Viscosity.
		Drying.	Burning.	Av.	Max.		Incipient Fusion.	Vitrification.	
26	Plastic	10%	6%	86	103	5.10%	2050°	2250°	2450°
27	Lean	10%	6%	59	67	11.07%	2000°	2150°	2300°
28	Very plastic	8%	3%	145	160	7.27%	2000°	2200°	2400°

The clay as it is mined is thrown into cars which are run to the foot of an incline up which they are drawn by a cable to the factory. The clay mixture is put through the usual chaser mill, each charge being tempered about four minutes. It is then carried on an endless belt to the pipe press. In their old building the company has Barber sewer-pipe presses, and Penfield presses in the new works. There are several

stories of slatted drying floors in each of the two factories, and the heat is supplied by coils of pipe on the lower floor. The diameters of sewer-pipe made are the usual ones up to 24 inches in diameter, inside measure. A second grade of sewer-pipe of the same sizes, manufactured here, is now used largely as a substitute for stone culverts at public road crossings. And in addition to these the company manufactures the following: Terracotta well tubing, 10 to 24 inches inside diameter, and 2 feet long; terracotta chimney flues; and farm drain tile 2½ to 12 inches in diameter.

The burning is done in circular down-draft kilns, 26 ft. in diameter and 8½ ft. high, with inclined grate bars in the fire-places. Soft clinker coal is used for fuel. There are 12 kilns altogether, with one stack for two kilns. (See Plate I, frontispiece, for a general view of the works.)

Flue linings and semi-fire-brick are also made and burned in the same kilns.

The company has an abundance of available clay, as it controls much land bordering the North Buffalo creek and has exploited the clay beds to a considerable extent. It has a complete modern plant, having recently more than doubled its capacity, and is turning out some excellent material.

This is about the usual composition of brick clays, with the exception of lime and magnesia, which are somewhat low.

#### METHODS OF BRICK MANUFACTURE.

All clay when made into building brick has to go through the following stages:

1. Preparation (crushing or tempering, or both).
2. Molding.
3. Drying.
4. Burning.

Various methods may be used in each stage of the manufacture, and this is especially the case in molding, and, therefore, four methods of manufacture are generally recognized, according to the type of machine used to shape the clay. These four processes are:

1. Soft-mud.
2. Stiff-mud.
3. Semi-dry press.
4. Dry press.

Each of these processes has certain advantages, and its applicability depends on the character of the clay, capacity desired, and capital available.

#### SOFT-MUD PROCESS.

In North Carolina this is the one most generally used. It is adaptable to almost any clay, and requires the least amount of capital.

**TEMPERING THE CLAY.**—The clays used are generally soft ones, such as require no grinding. They are first tempered with water. This is done either by throwing the clay into a large rectangular pit behind the molding machine, pouring water over it and allowing it to soak, or else tempering it in ring-pits. These consist of circular pits 15-20 feet in diameter and 2-3 feet deep. In each pit there revolves a large iron wheel attached to a post in the centre, and so geared that it travels back and forth from the centre to the circumference of the pit as it travels around. The clay is shoveled into the pit, water poured over it and the mass allowed to soak for 12 hours, and it is then mixed by the wheel for about six hours more. This is by far the best method of tempering clay for the soft-mud process, for it mixes the clay into homogeneous mass, which is something a soak pit does not do.

Many small manufacturers in the South have a rather crude arrangement for tempering their clay. It consists of a vertical rectangular box, in which there is set an upright shaft with cross-arms. The clay is thrown in at the top, and by the revolution of the shaft, operated by horse-power, it is forced slowly downward and out at the bottom.

**REQUISITES OF BRICK-CLAYS.**

The more impure clays are generally used for the manufacture of building brick. They should burn to a good red color, preferably at a temperature not greater than 2000° F. or 2100° F. They should have enough fluxes to cement the particles to a hard and dense body at the above temperature. From 5-7% of iron is desirable, as this amount has generally been found to exert the best coloring action. A large amount of lime is undesirable, for it brings the temperatures of fusion and incipient vitrification too close together, although Seger has shown that with care a good brick may be made from a clay containing 20-25% of calcium carbonate. Its tendency, as previously stated (chemical properties of clays), is to lessen the shrinkage. If brick-clays contain lime, it should be finely and evenly disseminated, for if in lumps, these are apt to split the burned brick (see p. 21).

Sand seems generally to decrease the plasticity and tensile strength, whether present in coarse grains as in the laminated black clay on the Cape Fear river at Prospect Hall, or in a finely divided condition as in the kaolin four miles west of Troy. It also diminishes the shrinkage to a variable extent. Indeed, sand is sometimes added to very plastic clays to facilitate molding and decrease the shrinkage in drying and burning. It should be borne in mind, however, that it is harmful to go to the other extreme and add too much sand, for the tendency is to produce a weak, porous brick, especially if hand-molded.

Fine-grained clays and very plastic ones generally require slow drying. The reason for this is that on account of the smallness of the pores the moisture cannot escape so readily, and the outer portion of the brick dries and shrinks quicker than the interior. The result is cracking. Rapid drying may be prevented somewhat by adding salt water to the clay; this is a common practice in portions of Missouri.<sup>1</sup>

Fine-grained clays very often have to be heated slowly in the early stages of burning, although in the case of fine-grained clays with an abundance of fine sand they can generally be heated rapidly, so far as the North Carolina clays are concerned.

The range of the various constituents in the North Carolina brick-clays is as follows:

*Range of Constituents in North Carolina Brick-Clays.*

	Range.	Average.
Silica .....	52-70	60.00
Alumina .....	13-28	18.00
Ferric oxide .....	1.5-11.5	6.00
Lime .....	0.10-2.5	0.60
Magnesia .....	0.10-1.5	0.40
Alkalies .....	0.20-4.5	2.00
Water .....	4-12	7.00
Total fluxes .....	3.5-17.5	9.00

<sup>1</sup> Mo. Geol. Survey, XI, p. 481.

courses of brick, called the "platting," are laid flatside down on the top of the kiln to keep the heat in. Fires are then built in both ends of the arches, and the interior of the kiln is gradually heated to the desired temperature.

Burning is the most important step in the manufacture of brick. It is important that the heat should be raised slowly during water-smoking and also while the combined water is being driven off, and, furthermore, that the temperature should be distributed as evenly as possible throughout the kiln, for it is a common fault at many of the smaller yards that the arches are almost melted while the upper courses can sometimes barely be called salmon brick. In this connection there may be mentioned the practice followed by some manufacturers of adding coal-dust to the brick to be placed in those parts of the kiln which do not receive sufficient heat. In burning, the coal-dust in the brick ignites and supplies additional heat where it is needed. The coal dust is added in the proportions of one bushel to clay for 1000 brick, and is added to the clay before it is tempered. Wood is the fuel commonly used in burning soft-mud brick. The arches are often closed by iron doors, and these should never be omitted, for a flood of cold air rushing into a mass of red-hot brick is sure to do damage.

If the heat is raised too rapidly, the outer part of the brick shrinks and becomes dense before the ferrous oxide of the interior has been converted to the ferric oxide, and a black core is generally to be seen in such cases; unequal shrinkage and consequent cracking also results from the same cause.

#### STIFF-MUD PROCESS.

**PREPARATION OF THE CLAY.**—This method of making brick is applicable to either shales or clays. In the case of the former they generally have to be prepared by grinding them in a dry pan. This consists of a large circular revolving iron pan about 9 feet in diameter (fig. 4, p. 97). In this there are two iron rolls weighing 3000-4000 pounds each, and which revolve by friction against the bottom of the pan. The outer part of the bottom is perforated by slits one-fourteenth to one-sixteenth inch diameter, according to the fineness to which the material is to be ground.

For softer shales and tough clays a disintegrator is used.

Many of the North Carolina manufacturers pass their clay first through a pair of rolls, but as in most instances where these are used the clay contains no stones and needs only tempering, the advantage of using the rolls is not apparent.

**TEMPERING THE CLAY.**—For a stiff-mud machine the tempering is generally done in a pugmill. This consists of a horizontal trough in

Pugmills are sometimes used in connection with soft-mud machines, but are more frequently used in connection with the stiff-mud process, and will be described under that head.

**MOLDING THE BRICK.**—The clay is molded by hand or in machines operated either by steam or horse-power. When the clay is molded by hand it is generally tempered somewhat softer, often too much so. A wooden mold is used. The molder takes a chunk of clay from his supply on a table near him, and forming it roughly he lifts it up and then throws it downward into the mold, which has been previously sanded on the inside to prevent the clay adhering. The mold is then reversed onto a pallet, the brick drops out and is carried off by a boy, the "off-bearer," and placed on the yard to dry.

A man can mold about 2500-3000 bricks per day by this method.

The day's work of molded brick, which have been spread out on the yard to dry, are turned on edge at the end of the day to permit equal drying. Sometimes a boy goes along the rows of brick and, with a flat board fastened to the end of a stick, stamps the brick in order to square them up in case the clay was too wet to hold its shape.

Hand-molding is a cheap method as far as cost of plant is concerned, but the capacity is small. Hand-made bricks are generally porous and light, as the clay receives little pressure in molding, but they are homogeneous in structure, and when hard-burnt are usually strong.

The celebrated Philadelphia red front brick were for a long time molded by hand and then re-pressed.

When soft-mud brick are molded by machine the clay is fed into the upper end of a rectangular box, which is really a vertical pugmill. The clay passes downward and is forced into a six-brick mold at the bottom; the latter, as soon as filled, being thrust out. Such machines have a capacity of about 20,000 brick per day. It requires from 5 to 7 men to operate one of these machines, that is, a shoveler, mold-sander, mold-lander, who receives the mold and trims off the superfluous clay, and two or three off-bearers to spread the brick on the yard.

**DRYING.**—Soft-mud bricks are generally dried in the sun. As this method requires considerable space, especially when large capacity is required, it is sometimes found desirable to dry the brick on pallets set one above the other on racks. This increases the drying capacity, avoids handling until the brick are set in the kiln, and there is no loss from washed brick. The drying takes a little longer.

**BURNING.**—Soft-mud bricks are usually burned in scove-kilns; that is, they are piled up in rectangular masses 35-40 courses high, and open spaces or arches are left at intervals in the bottom of the pile, these arches running through the mass.

The exterior of the "kiln" is daubed over with mud, and one or two

courses of brick, called the "platting," are laid flatside down on the top of the kiln to keep the heat in. Fires are then built in both ends of the arches, and the interior of the kiln is gradually heated to the desired temperature.

Burning is the most important step in the manufacture of brick. It is important that the heat should be raised slowly during water-smoking and also while the combined water is being driven off, and, furthermore that the temperature should be distributed as evenly as possible throughout the kiln, for it is a common fault at many of the smaller yards that the arches are almost melted while the upper courses can sometime barely be called salmon brick. In this connection there may be mentioned the practice followed by some manufacturers of adding coal-dust to the brick to be placed in those parts of the kiln which do not receive sufficient heat. In burning, the coal-dust in the brick ignites and supplies additional heat where it is needed. The coal dust is added in the proportions of one bushel to clay for 1000 brick, and is added to the clay before it is tempered. Wood is the fuel commonly used in burning soft-mud brick. The arches are often closed by iron doors, and these should never be omitted, for a flood of cold air rushing into a mass of red-hot brick is sure to do damage.

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#### STIFF-MUD PROCESS.

PREPARATION OF THE CLAY.—This method of making brick is applicable to either shales or clays. In the case of the former they generally have to be prepared by grinding them in a dry pan. This consists of a large circular revolving iron pan about 9 feet in diameter (fig. 4 p. 97). In this there are two iron rolls weighing 3000-4000 pounds each, and which revolve by friction against the bottom of the pan. The outer part of the bottom is perforated by slits one-fourteenth to one sixteenth inch diameter, according to the fineness to which the material is to be ground.

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FIG. 1.—STIFF-MUD AUGER END-CUT BRICK MACHINE.

Shows a bar of clay issuing from the die of the machine. This is cut across by a wire at proper intervals, thus dividing it into brick.



FIG. 2.—RE-PRESSING BRICK MACHINE.

The brick to be re-pressed are brought from the moulding machine on a belt (as shown in the foreground), from which they are taken by a workman who places them, two at a time, into the machine.





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FIG. 1.—INTERIOR VIEW OF A CONTINUOUS BRICK-KILN.



FIG. 2.—EXTERIOR VIEW, CONTINUOUS BRICK-KILN.

the charging holes in the roof. As each chamber is filled the temporary (often paper) partition between it and the next one is put up, the object of this being simply to prevent the draft from passing straight through the whole kiln.

After each chamber is filled the two entrances are bricked up, leaving a charging space, which is covered by an iron door. The kiln is started by building a fire in the doorway of the first chamber and gradually heating it up to the desired temperature. Coal slack is also charged through the openings in the top. Many manufacturers no longer use the top openings, but feed all the fuel through the doorways.

The important principle of the continuous kiln is that the heat from this burned chamber is conducted into the next one either through the flues in the wall or else through sheet-iron pipes placed to connect the roof openings. In this way the heat raises the temperature of the next chamber, so that less fuel need be used. When the kiln is once started it takes from 200-300 pounds of fuel per 1000 brick.

The heat from a burning chamber cannot as a rule be carried safely through more than three or four chambers before taking it off to the chimney. The reason for this is that the hot-air collects moisture from the brick in these chambers which are being heated up; it will easily be seen that if carried through too many chambers the air will lose so much heat that instead of gathering moisture it will begin to deposit it on the brick.

It is sometimes necessary to aid the draft of a continuous kiln by means of a small fan. The number of chambers in the kiln depends on the size of the yard and available capital.

Continuous kilns are used in this country for burning common and front brick, paving brick and fire-brick.

No continuous kilns are in use in North Carolina, so that the illustrations shown are from one at the Catskill (N. Y.) Paving-Brick Works. Fig. 1 of Plate IX shows the interior view of the kiln, which is empty, while fig. 2 of the same plate shows the exterior view.

#### DRY-PRESS PROCESS.

This method is applicable to a variety of clays, but not to very sandy ones, which have little cohesive nature. The advantages of it are wide range of character permissible in clays used, the brick made are sharp-edged and smooth, and the green brick can generally be set directly in the kiln.

The disadvantages of this method are, the necessity of weathering the clay, increased cost of plant, and limited capacity.

Dry-press brick when properly burned are as strong as other brick, but if underburned they are easily affected by the weather.



FIG. 1.—UP-DRAFT BRICK-KILNS, FOR BURNING COMMON BRICK, AT THE STATE PENITENTIARY, RALEIGH, N. C. (See page 98.)



FIG. 2.—DOWN-DRAFT BRICK-KILN, EUDLAY TYPE. (See also page 141.)







FIG. 1.—UP-DRAFT BRICK-KILNS, FOR BURNING COMMON BRICK, AT THE STATE PENITENTIARY, RALEIGH, N. C. (See page 98.)



FIG. 2.—DOWN-DRAFT BRICK-KILN, EUDLAY TYPE. (See also page 141.)

the finer mesh being used for front brick. The clay should not contain too much moisture, as otherwise it clogs the screen.

**MOLDING THE BRICK.**—The dry-press consists essentially of a steel mold box with movable top and bottom. The clay is fed into the mold automatically, and the plunger descends into the mold from above, the pressure being applied by means of a toggle-joint or cam. After the clay is pressed the plunger rises, as does also the bottom of the mold, until the brick is level with the table, on which it is pushed forward by the charger as it advances to refill the mold. The brick are set on hand-cars and carried off to the kilns.

If the clay is very dry the edges are apt to crumble, and the brick will not bear much handling. To avoid this the clay is sometimes discharged from the screen into a pugmill, where it is moistened with steam. This gives a brick with sharper edges and one which bears handling better. The term *semi-dry press* is used when the clay is moistened somewhat.

There are numerous types of dry-press machines, among which may be mentioned those of the Boyd (fig. 5, p. 100), Simpson, Whittaker, and Chambers patterns. The slower the pressure is applied in molding the brick the less air will there be enclosed in it, and the less will be the danger of its bursting by the expansion of the air.

**BURNING.**—Dry-press brick are burned in either up-draft or down-draft kilns. This process has to be conducted very slowly, for both the drying and water-smoking have to be done in the kiln, and, on account of the dense nature of the brick, the water can only escape slowly. Drying and water-smoking may therefore take from six to eight days. In burning front brick it is important that as few as possible should be exposed to the direct action of the flames. In up-draft kilns the arch brick are generally warped and discolored, while in down-draft kilns the top courses are generally fire-flashed and also discolored from the ashes of the fuel. These top brick are harder burned than the bottom ones, and while useless for front brick, if not cracked they are often desirable for walks or sewers.

The down-draft kiln is preferable for burning front brick, as there is less loss in the form of overburned or underburned brick. Plate X, fig. 2, shows the Eudaly type of down-draft kiln, which is in common use.

## CHAPTER IX.

### BRICK-CLAY DEPOSITS IN NORTH CAROLINA.

#### CLAYS IN BLADEN COUNTY.

NEAR PROSPECT HALL.—Following down the Cape Fear river Fayetteville, after passing Willis creek, there begin to appear quantities of black clay in the bluffs along the river. One of the sections is to be seen in a bluff 60 feet high on the property of Liam Whitted at Prospect Hall (see Plate XI, fig. 1, p. 110).

The upper 20 feet of the bluff are sand and gravel often he stained with iron, but the lower forty feet are mostly black clay, ro separated into three somewhat lens-shaped beds, as follows:

Black, sandy clay, 8-10 feet (field sample No. 11).

Sand and sandstone, 10 feet.

Black, sandy clay, 8 feet (field sample No. 10).

Black clay, 4 feet, exposed at base of bluff (field sample No. 12).

The upper black sandy clay of the section (No. 11) has in 1 abundant mica scales, and sometimes coarse sand grains. It s slowly to large scaly fragments. Pyrite and lignite are both scat sparingly through the clay, but the pyrite is mostly in small g The addition of 38% of water gave a mass that was lean and g This paste shrunk 6% in drying and 8% in burning, giving a total sh age of 14%. Air-dried briquettes of this paste had an average t strength of 64 lbs. per square inch and a maximum of 77 lbs square inch. Incipient fusion occurs at 1900° F., vitrification at 2 viscosity at 2300°. It burns to a deep red, dense body.

The composition of this clay is:

#### *Analysis of Brick-clay (No. 11), Prospect Hall.*

Molsture .....	4.50
Silica (total) .....	56.13
Alumina .....	17.80
Ferric oxide .....	5.85
Lime .....	.10
Magnesia .....	.79
Alkalies .....	2.45
Water (loss on ignition) .....	11.60
Total .....	99.22
Free sand .....	27.18
Total fluxes .....	7.29
Specific gravity .....	2.34

Ferric oxide .....	3.16
Ferrous oxide .....	.87
Lime .....	.20
Magnesia .....	.32
Alkalies .....	1.85
Water (loss on ignition) .....	6.17
<b>Total .....</b>	<b>99.74</b>
Clay substance .....	49.34
Free sand .....	50.40
Total fluxes .....	6.20
Specific gravity .....	2.50

The iron is mostly oxidized, as will be seen from the analysis and also indicated by the color of the clay.

The under clay at this yard goes by the name of fire-clay. It is a coarse-grained clay, full of mica scales and small angular quartz grains. In water it slakes quickly and completely, and on the addition of 28% of water gave a workable and moderately plastic paste which shrunk 7% in drying and 4% in burning, giving a total shrinkage of 11%. The average tensile strength of the air-dried briquettes made from this clay was 58 lbs. per square inch, with a maximum of 60 lbs.

Incipient fusion occurs at 2050° F., vitrification at 2250° F., and viscosity at 2450° F. The clay burns gray buff. The composition of the clay is as follows:

*Analysis of lower Brick-clay ("fire-clay") (No. 58), Penniman's.*

	Total portion.	Insoluble portion.
Moisture .....	.80	
Silica (total) .....	70.66	55.70
Alumina .....	17.21	.40
Ferric oxide .....	3.44	.56
Lime .....	.10	
Magnesia .....	.07	
Alkalies .....	2.45	1.32
Water (loss on ignition).....	5.00	
<b>Total .....</b>	<b>99.73</b>	<b>57.98</b>
Total fluxes .....	7.16	
Specific gravity .....	2.48	

From the above analysis we obtain:

Clay substance .....	41.75
Quartz .....	54.30
Feldspar. ....	3.68

This clay is not unlike the bottom clay at Bethania, but contains more free sand. The grains of the latter are mostly quartz, as seen from the rational analysis.

This type of clay is not uncommon in North Carolina, the clays at Grover being of this kind, but they contain less iron. The predominant character, however, is the fine-grained clay substance with the coarse quartz grains scattered through it.

Mr. Penniman uses the upper clay for making common brick and also for re-pressed brick, for it burns to a good red color. The brick are molded in a Sword's machine, dried in the sun and burned in up-draft open kilns with permanent side walls, of 185,000 capacity. The fuel is coal.

The brick made from the lower clay are burned in the same kiln and at the same time as the red clay. They are re-pressed. The chief use of the lower clay brick is for boiler and furnace foundations and for furnaces requiring only a low degree of heat. The bricks are white or yellowish-white, and not burned very hard.

It is probable that a mixture of the upper and lower clay would make a paving brick, although if a more plastic and slightly more fusible clay than the upper one could be mixed with the lower clay, still better results would be obtained. Such clays are to be found in many of the lowlands along the valleys near Asheville.

CLAYS NEAR ASHEVILLE AND BILTMORE.—The French Broad river near Asheville is bordered at several points by broad stretches underlain by clays of good quality for various purposes. Such a deposit has been worked at Biltmore with eminent success, the products being common and pressed brick, drain tile, and paving brick. The deposit has been covered up now to permit land improvements, but the same belt of clay land borders the river at other points.

It should be noted that the methods and machinery used at Biltmore were of the most approved type.

Poor products may result very often as much from carelessness in manipulation and the use of the wrong appliances and methods as in the use of improper clay.

The other brickyards around Asheville are working residual clays for making common brick to supply a local demand.

CLAYS NEAR FLETCHER.—The Buncombe Brick Co. at this locality is engaged in the manufacture of both common, pressed and paving brick. Their main bank is a light gray clay of slightly plastic and somewhat gritty feel. It is fine-grained and slakes slowly. The addition of 25.5% of water was required to give a workable mass, which shrunk 4% in drying and 7% in burning, making a total shrinkage of 11%. The air-dried briquettes had an average tensile strength of 37 lbs. per square inch and a maximum of 40 lbs. per square inch.

Ferric oxide .....	3.16
Ferrous oxide .....	.67
Lime .....	.20
Magnesia .....	.32
Alkalies .....	1.85
Water (loss on ignition) .....	6.17
Total .....	99.74
Clay substance .....	49.34
Free sand .....	50.40
Total fluxes .....	6.20
Specific gravity .....	2.50

iron is mostly oxidized, as will be seen from the analysis and indicated by the color of the clay.

under clay at this yard goes by the name of fire-clay. It is a grained clay, full of mica scales and small angular quartz grains. It slakes quickly and completely, and on the addition of 28% water gave a workable and moderately plastic paste which shrunk on drying and 4% in burning, giving a total shrinkage of 11%. The tensile strength of the air-dried briquettes made from this clay was 60 lbs. per square inch, with a maximum of 60 lbs.

Concentric fusion occurs at 2050° F., vitrification at 2250° F., and complete fusion at 2450° F. The clay burns gray buff. The composition of the clay is as follows:

*Analysis of lower Brick-clay ("fire-clay") (No. 58), Penniman's.*

	Total portion.	Insoluble portion.
Moisture .....	.80	
Silica (total) .....	70.66	55.70
Alumina .....	17.21	.40
Ferric oxide .....	3.44	.56
Lime .....	.10	
Magnesia .....	.07	
Alkalies .....	2.45	1.32
Water (loss on ignition).....	5.00	
Total .....	99.73	57.98
Total fluxes .....	7.16	
Specific gravity .....	2.48	

From the above analysis we obtain:

Clay substance .....	41.75
Quartz .....	54.30
Feldspar. ....	3.68

This clay is not unlike the bottom clay at Bethania, but contains more free sand. The grains of the latter are mostly quartz, as shown from the rational analysis.

This type of clay is not uncommon in North Carolina, the clay at Grover being of this kind, but they contain less iron. The predominant character, however, is the fine-grained clay substance with coarse quartz grains scattered through it.

Mr. Penniman uses the upper clay for making common brick also for re-pressed brick, for it burns to a good red color. The brick is molded in a Sword's machine, dried in the sun and burned in open kilns with permanent side walls, of 185,000 capacity. The fuel is coal.

The brick made from the lower clay are burned in the same kiln at the same time as the red clay. They are re-pressed. The chief use of the lower clay brick is for boiler and furnace foundations and furnaces requiring only a low degree of heat. The bricks are white or yellowish-white, and not burned very hard.

It is probable that a mixture of the upper and lower clay would make a paving brick, although if a more plastic and slightly more fusible than the upper one could be mixed with the lower clay, still better results would be obtained. Such clays are to be found in many of the lowlands along the valleys near Asheville.

CLAYS NEAR ASHEVILLE AND BILTMORE.—The French Broad river near Asheville is bordered at several points by broad stretches underlain by clays of good quality for various purposes. Such a deposit has been worked at Biltmore with eminent success, the products being common and pressed brick, drain tile, and paving brick. The deposit has been covered up now to permit land improvements, but the same belt of land borders the river at other points.

It should be noted that the methods and machinery used at Biltmore were of the most approved type.

Poor products may result very often as much from carelessness in manipulation and the use of the wrong appliances and methods as from the use of improper clay.

The other brickyards around Asheville are working residual clays and making common brick to supply a local demand.

CLAYS NEAR FLETCHER.—The Buncombe Brick Co. at this locality is engaged in the manufacture of both common, pressed and paving brick. Their main bank is a light gray clay of slightly plastic consistency with a somewhat gritty feel. It is fine-grained and slakes slowly. The absorption of 25.5% of water was required to give a workable mass, which shrank 4% in drying and 7% in burning, making a total shrinkage of 11.5%. The air-dried briquettes had an average tensile strength of 37 lbs. per square inch and a maximum of 40 lbs. per square inch.



Incipient fusion occurs at 2000° F., vitrification at 2200° F., and viscosity at 2400° F.

The chemical composition of the clay is:

*Analysis of Brick-clay (No. 65), near Fletcher.*

Moisture .....	1.10
Silica (total) .....	75.08
Alumina .....	13.73
Ferric oxide .....	3.47
Lime .....	.30
Magnesia .....	.17
Alkalies .....	1.48
Water (loss on ignition) .....	4.65
Total .....	99.98
Clay substances .....	45.18
Free sand .....	55.80
Total fluxes .....	5.42
Specific gravity .....	2.41

**CLAYS IN BURKE COUNTY.**

NEAR MORGANTON.—The clay underlying the terrace along the river two miles west of the town becomes more sandy in character towards the river. A sample from the brickyard of Mr. McDowell along the river had 60% of sand, while along the road, back from the river, there was only 54%.

The clay as exposed in McDowell's brick-clay bank (No. 52) is a loose, sandy, coarse clay, with abundant mica scales and quartz grains. It slakes very quickly and completely to its component grains. The addition of 22% of water gave a lean but workable mud which shrunk 6% in drying and 5% in burning, giving a total shrinkage of 11%.

The average tensile strength of the air-dried briquettes was 56 lbs. per square inch, with a maximum of 83 lbs.

Incipient fusion occurs at 1950° F., vitrification at 2100° F., and viscosity at 2250° F. The clay burns dark red at 2100° F.

The analysis of it gave:

*Analysis of Brick-clay (No. 52), McDowell's clay bank.*

Moisture .....	1.80
Silica (total) .....	67.03
Alumina .....	16.88
Ferric oxide .....	6.50
Lime .....	1.00
Magnesia .....	1.16
Alkalies .....	.90
Water (loss on ignition) .....	4.78
Total .....	100.05

Clay substance .....	39.90
Free sand .....	60.05
Total fluxes .....	9.56
Specific gravity .....	2.61

The clay is used for making common brick, but they are molded in ordinary hand-molds and burned barely to incipient fusion; with more care and better machinery a very good brick could be made from it.

Probably there could be found a more plastic clay in the lowlands between the railroad and the North Carolina Insane Asylum.

#### CLAY IN CLEVELAND COUNTY.

**NEAR GROVER.**—Occurring in the region around Grover are several beds of surface clays which have no connection with the so-called fire-clays previously mentioned (p. 81). At the works of the Cleveland Brick Company just south of Grover, one of these beds has been opened up and consists of an upper bed of tough, red, mottled clay, 6 feet thick, and an under bed of very plastic clay not less than 3 feet thick.

The under clay (No. 46) is a gritty clay with small mica flakes and coarse sand grains. It is slow in slaking. 35% of water was required to give a workable mass that shrunk 9% in drying and 6.5% in burning, giving a total shrinkage of 15.5%. Air-dried briquettes of the clay had an average tensile strength of 98 lbs. per square inch and a minimum of 115 lbs. per square inch. Incipient fusion occurs at 1900° F., vitrification at 2100° F., and viscosity at 2300° F. The clay burns to a rather light red.

The analysis of the clay gives:

##### *Analysis of Cleveland Brick Co's. under Clay (No. 46), just S. of Grover.*

Moisture .....	1.18
Silica (total) .....	61.75
Alumina .....	23.30
Ferric oxide .....	3.34
Ferrous oxide .....	.50
Lime .....	.27
Magnesia .....	.25
Alkalies .....	1.31
Water (loss on ignition) .....	7.75
Total .....	99.65
Clay substance .....	60.62
Free sand .....	39.05
Total fluxes .....	5.67
Specific gravity .....	2.36

The upper clay is far less plastic, but very tough. It also required 35% of water to make a workable paste, which was gritty to the feel and somewhat plastic. This clay shrunk 7.5% in drying and 5% in burning, giving a total shrinkage of 12.5%. The average tensile strength of the air-dried briquettes was 42 lbs. per square inch with a maximum of 51 lbs. Incipient fusion occurred at 1950° F., vitrification at 2150° F., and viscosity at 2350° F. The clay burns red.

The composition of this clay is as follows:

*Analysis of Cleveland Brick Co.'s upper Clay (No. 47), just S. of Grover.*

Moisture .....	.63
Silica (total) .....	65.45
Alumina .....	20.02
Ferric oxide .....	4.18
Lime .....	.25
Magnesia .....	.29
Alkalies .....	1.51
Water (loss of ignition) .....	6.58
<hr/>	
Total .....	98.91
Clay substance .....	47.06
Free sand .....	51.45
Total fluxes .....	6.23
Specific gravity .....	2.61

While the upper clay is not as strong as the lower, still it burns easier to a red brick and shrinks less in burning.

The pit is about 300 feet from the yard, and the clay is hauled in carts. The tempering is done in a long open pugmill of Chambers's manufacture. Molding is done in a Chambers's auger automatic end-cut machine. A pair of rolls were formerly used for breaking the clay, but were found very unsatisfactory. A standard dryer heated by steam-pipes is used. Exhaust steam is used in the daytime and live steam at night.

The brick are burned either in scove kilns or circular down-draft ones. They are 16 feet in diameter, and there is one stack for every two kilns, but Mr. Eskridge is about to put a number of small chimneys on each kiln.

The fire-brick are burned in the circular kiln. They are used for the roof of the roasting furnaces at the Blacksburg (South Carolina) acid works, and wear well. The furnace has a diameter of 20 feet, and the rise from circumference to centre is 8 inches.

The hard red brick are used around the acid works and resist the action of the acid very well.

This clay is not unlike many of the alluvial clays in other parts of

North Carolina, and they show very well the influence of proper turning and machinery in producing good results.

#### CLAY IN CUMBERLAND COUNTY.

NEAR FAYETTEVILLE.—South of the town are extensive beds of elementary clays, whose general section involves 2-3 feet of coarse sand underlain by at least eight feet of clay, and sometimes probably more. The clays are best exposed at Poe & Bros.' yard, a half mile south of Fayetteville. The clay as exposed here is a fine-grained, tough, bluish white clay with frequent thin iron stains, which give it a mottled appearance. In some portions of the bank the clay is very smooth and free from iron stains, and has been used for stoneware. (Plate fig. 2.)

At the south of the pit is a bed of very tough clay, fine-grained and broken by numerous small joints running in every direction. This clay is not used, as it is claimed to be too tough to work.

A sample of the average run of the bank, excluding the top sand and the toughest clay, which is not used, showed the clay to be a somewhat gray medium-grained, tough clay which slakes quickly to grains  $\frac{1}{16}$  to  $\frac{1}{8}$  in diameter. It required the addition of 28% of water to make a workable mud, which felt quite plastic. This mass shrunk 8.5% in drying and 5% in burning, giving a total shrinkage of 13.5%. The air-briquettes of this paste had an average tensile strength of 144 lbs. per square inch and a maximum of 175 lbs. per square inch.

Incipient fusion occurs at 1900° F., vitrification at 2050° F., and viscosity at 2200° F. The clay burns deep red.

The chemical composition of the clay is as follows:

#### *Analysis of Poe's Brick-clay (No. 14), $\frac{1}{2}$ mile S. of Fayetteville.*

Moisture .....	2.48
Silica (total) .....	64.93
Alumina .....	17.08
Ferric oxide .....	5.57
Lime .....	.43
Magnesia .....	.59
Alkalies .....	3.85
Water (loss of ignition) .....	6.58
<hr/>	
Total .....	101.51
Clay substance .....	53.13
Free sand .....	45.90
Total fluxes .....	10.44
Specific gravity .....	2.55

A sample of the so-called "tough" clay was also tested with the following results. It is a dense, somewhat gritty clay which is



FIG. 1.—BLACK CLAY ALONG CAPE FEAR RIVER, AT PROSPECT HALL.  
(See page 102.)



FIG. 2.—POE BROTHERS' CLAY BANK, FAYETTEVILLE, N. C.



slowly to rounded granules of variable size, mostly above  $\frac{1}{16}$  in. Little mica was noticeable. It required the addition of 28.5% of water to make an easily worked paste, which shrank 9.8% in drying and 7% in burning, giving a total shrinkage of 16.8%. Air-dried briquettes of this clay had an average tensile strength of 84 lbs. per square inch and a maximum of 120 lbs. per square inch. Incipient fusion occurs at 1850° F., vitrification at 2050° F., and viscosity at 2250° F. The clay burns deep red, and requires somewhat slow heating to prevent cracking. The composition of the clay as shown by analysis is as follows:

*Analysis of the "tough clay" (No. 15), Poe's bank,  $\frac{1}{2}$  mile S. of Fayetteville.*

Molsture .....	3.23
Silica (total) .....	58.17
Alumina .....	20.10
Ferric oxide .....	7.43
Lime .....	.60
Magnesia .....	.77
Alkalies .....	2.60
Water (loss of ignition) .....	7.34
<hr/>	
Total .....	100.24
Clay substance .....	48.09
Free sand .....	52.15
Total fluxes .....	11.40
Specific gravity .....	2.45

The greater toughness of this clay is due to its density.

This "tough clay" could probably be mixed advantageously with the other. As this clay is manufactured into a very good brick, it may be well to mention the method followed. The clay and sand are first dumped into soak pits. From these they are shoveled into a Penfield plunger machine and issue from this onto the cutting table, where they are cut up into brick, the frame carrying the cutting wires being operated by hand-power. The drying is usually done on pallets and proceeds very slowly. The burning is done in permanent side-wall, up-draft kilns, having a capacity of 170,000. Re-pressing the brick has been attended with favorable results.

#### CLAY IN FORSYTH COUNTY.

NEAR BETHANIA.—The largest brick-making plant in the State is situated at this locality. It is owned by Messrs. Carter and Shepard. (Plate XII, fig. 1, p. 120.)

The clay bank adjoins the yard and consists of a gray clay, the upper portions of which are intermixed with the wash of residual clay from the neighboring slopes. The lower portion, of which there is an

Alkalies .....	.84
Water (loss on ignition) .....	8.75
Total .....	99.27
Clay substance .....	50.99
Free sand .....	48.05
Total fluxes .....	6.98
Specific gravity .....	2.47

This clay should make a first-class brick that would stand re-pressing. In composition and physical properties it is closely similar to the clay for pottery dug northwest of Lincolnton, but is more sandy in its nature.

#### CLAY IN GUILFORD COUNTY.

NEAR GREENSBORO.—Both residual and sedimentary clays occur in abundance around the town, and both are utilized by the brick manufacturers. The *Greensboro Brick and Tile Company's yard* is located on the northern edge of the town along the road to Pomona. The clay is a reddish residual clay resulting from the decomposition of gneissic rock, and opened up to a depth of 8 feet. This material is somewhat more sandy in portions of the bank, but all of it is soft. A sample of this clay was found to slake easily to its component grains. It required 28% of water to produce a workable mass, which shrunk 9% in drying and 6% in burning, making a total shrinkage of 15%. This paste was moderately plastic. Air-dried briquettes of the clay had an average tensile strength of 85 lbs. per square inch and a maximum of 96 lbs. per square inch. Incipient fusion occurs at 2050° F., vitrification at 2250° F., and viscosity at 2450° F. The clay burns to a red body.

Its composition is as follows:

#### *Analysis of Greensboro Brick & Tile Co's. Clay (No. 24).*

Moisture .....	1.64
Silica (total) .....	56.81
Alumina .....	20.62
Ferric oxide .....	6.13
Lime .....	.65
Magnesia .....	.58
Alkalies .....	4.47
Water (loss on ignition) .....	8.60
Total .....	99.50
Clay substance .....	58.85
Free sand .....	40.65
Total fluxes .....	11.83
Specific gravity .....	2.44



Magnesia .....	.16
Alkalies .....	1.42
Water (loss on ignition) .....	8.80
<b>Total</b> .....	<b>100.22</b>
Clay substance .....	67.44
Free sand .....	32.78
<b>Total fluxes</b> .....	<b>13.70</b>
Specific gravity .....	2.51

upper clay contains more iron and burns to a deeper red, but it does not possess the tenacity or plasticity that the lower clay does.

**TER AND SHEPARD'S CLAY BANK.**—This clay at Bethania is used for brick and drain tile. It is first put through rolls and then a pugmill, in which it is molded in a Steele auger machine. The drying is done on pallet racks or on heated floors. The brick are burned in a kiln and are of a deep red color, but full of laminations. The clay were prepared more thoroughly, and more of the under clay used, it would probably give better results.

#### CLAY IN GASTON COUNTY.

**AT MOUNT HOLLY.**—The terraces along the Catawba river are well developed around Mount Holly and furnish an abundance of clay. About one-quarter mile south of town this clay has been opened up for the manufacture of brick. The deposit lies at the shore line of the river and about 35 feet above the river. It is not less than seven feet thick and underlain by sand and gravel. Brick were formerly made from it by Holobaugh, but the yard is no longer running.

The clay is somewhat gritty and slakes slowly but completely. A few scales are scattered through it.

The addition of 29% of water gave a very plastic paste, which shrunk on drying and 4.5% in burning, giving a total shrinkage of 12.5%. The average tensile strength of the air-dried briquettes was 131 lbs. per square inch with a maximum tensile strength of 160 lbs. per square inch.

Incipient fusion occurs at 1950° F., vitrification at 2100° F., and plasticity at 2250° F. The clay burns to a close red body.

The analysis of this clay yielded as follows:

#### *Analysis of Brick-clay (No. 60), ¼ mile S. of Mt. Holly.*

Moisture .....	1.43
Silica (total) .....	61.28
Alumina .....	20.83
Ferric oxide .....	5.51
Lime .....	.40
Magnesia .....	.14

Alkalies .....	.84
Water (loss on ignition) .....	8.75
<hr/>	
Total .....	99.27
Clay substance .....	50.99
Free sand .....	49.05
Total fluxes .....	6.98
Specific gravity .....	2.47

This clay should make a first-class brick that would stand re-pressing. In composition and physical properties it is closely similar to the clay for pottery dug northwest of Lincolnton, but is more sandy in its nature.

#### CLAY IN GUILFORD COUNTY.

NEAR GREENSBORO.—Both residual and sedimentary clays occur in abundance around the town, and both are utilized by the brick manufacturers. The *Greensboro Brick and Tile Company's yard* is located on the northern edge of the town along the road to Pomona. The clay is a reddish residual clay resulting from the decomposition of gneissic rock, and opened up to a depth of 8 feet. This material is somewhat more sandy in portions of the bank, but all of it is soft. A sample of this clay was found to slake easily to its component grains. It required 28% of water to produce a workable mass, which shrunk 9% in drying and 6% in burning, making a total shrinkage of 15%. This paste was moderately plastic. Air-dried briquettes of the clay had an average tensile strength of 85 lbs. per square inch and a maximum of 96 lbs. per square inch. Incipient fusion occurs at 2050° F., vitrification at 2250° F., and viscosity at 2450° F. The clay burns to a red body.

Its composition is as follows:

#### *Analysis of Greensboro Brick & Tile Co's. Clay (No. 21).*

Moisture .....	1.64
Silica (total) .....	56.81
Alumina .....	20.62
Ferric oxide .....	6.13
Lime .....	.65
Magnesia .....	.58
Alkalies .....	4.47
Water (loss on ignition) .....	8.60
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Total .....	99.50
Clay substance .....	58.85
Free sand .....	40.65
Total fluxes .....	11.83
Specific gravity .....	2.44

The high per cent. of alkalies is evidently due to much undecomposed feldspar. A very good building brick is made from this clay. The plant includes a pair of rolls, Freese disintegrator and Freese side-cut auger machine. The brick are dried on a brick floor heated by hot air passing through flues underneath. They have three Morrison kilns in which soft coal is used. Re-pressing has been tried with fair results.

*Dean's brickyard* is on the southern side of town, and the clay is very similar to that at the Greensboro Brick and Tile Company's yard.

It is a leafy, gritty clay, with abundant grains of quartz, feldspar and mica. In water it slakes easily to its component grains.

It absorbed 28% of water in being worked into a paste, which shrunk 10% in drying and 6% in burning, giving a total shrinkage of 16%. The average tensile strength of air-dried briquettes was 66 lbs. per square inch, while the maximum was 77 lbs. per square inch. Incipient fusion occurred at 2100° F., vitrification at 2300° F., and viscosity at 2400° F. The clay burns red. Its composition is shown by the following analysis:

*Analysis of Dean's Brick-clay (No. 30) pit, Greensboro.*

Moisture .....	1.90
Silica (total) .....	50.27
Alumina .....	22.31
Ferric oxide .....	6.69
Lime .....	.25
Magnesia .....	.13
Alkalies .....	.90
Water (loss on ignition).....	9.00
<hr/>	
Total .....	100.45
Clay substance .....	67.20
Free sand .....	33.25
Fluxes .....	7.97
Specific gravity .....	2.46

This clay is used for the manufacture of common brick. It is tempered in a ring pit, molded by hand, dried in the sun, and burned in **Pe** **sc**ove kilns. The product is burned little beyond incipient fusion.

*Watson's brickyard* uses the same clay and methods as are used at **D**ean's yard, just described.

*Kirkpatrick's brickyard* is situated along North Buffalo creek, and **th**e clay is a portion of the deposit to be found more or less continuously **al**ong the creek all the way up to Pomona. It is a gray, gritty clay, **de**nse and tough, and slakes slowly to irregular granules.

It required the addition of 30% of water to make a workable paste, which shrunk 11% in drying and 5% in burning, giving a total shrinkage of 16%. Air-dried briquettes of the very plastic paste had an average

tensile strength of 220 lbs. per square inch with a maximum of 232 lbs. per square inch. Incipient fusion occurs at 1900° F., vitrification at 2100° F., and viscosity at 2300° F. It burns to a dense red body, but requires slow heating. The composition is indicated by the following analysis:

*Analysis of Kirkpatrick's Brick-clay (No. 31), Greensboro.*

Moisture .....	1.50
Silica (total) .....	69.70
Alumina .....	12.87
Ferric oxide .....	6.13
Lime .....	2.55
Magnesia .....	.57
Alkalies .....	2.79
Water (loss on ignition) .....	4.08
<b>Total .....</b>	<b>100.19</b>
Clay substance .....	35.27
Free sand .....	64.92
Fluxes .....	12.04
Specific gravity .....	2.48

The clay is discharged directly into a steel end-cut auger machine, heated on drying floors, and burned in scove kilns.

**CLAY IN HALIFAX COUNTY.**

**NEAR ROANOKE RAPIDS.**—There has been considerable demand for brick at this locality for use in the construction of large cotton mills being erected at this point. The clays used occur along or near the Roanoke river, a few hundred yards south of the cotton mills. The section is in general as follows:

Yellowish sandy clay (sample No. 1) .....	2 to 5 ft.
Plastic clay (exposed) (sample No. 2) .....	6 to 8 ft.

This upper sandy clay is coarse-grained and contains numerous small concretions of sand cemented by limonite. A sample of this upper clay was tested with the following results: The sandy, moderately coarse-grained yellow clay slaked extremely slowly on account of its density. It required 25% of water to produce a workable paste, which to the feel was very lean. This paste shrunk 8% in drying and 5% in burning, giving a total shrinkage of 13%. Air-dried briquettes of the mud had an average tensile strength of 46 lbs. per square inch and a maximum strength of 50 lbs. per square inch. Incipient fusion occurred at 1900° F., vitrification at 2050° F., and viscosity at 2250° F.

At 1900° the clay burned to a reddish, porous body, but at 2050°

was fairly dense, but deep reddish brown. The little ferruginous concretions fuse to black spots in burning.

The following is the composition of this upper sandy clay.

*Analysis of upper sandy Clay (No. 1), Roanoke Rapids.*

Moisture .....	1.63
Silica (total) .....	67.55
Alumina .....	13.16
Ferric oxide .....	8.54
Lime .....	.17
Magnesia .....	.28
Alkalies .....	2.65
Water (loss on ignition) .....	5.08
Total .....	99.06
Clay substance .....	41.98
Free sand .....	57.08
Total fluxes .....	11.64
Specific gravity .....	2.39

The insoluble residue ("free sand") in the above indicates the sandy character of the clay and the reason of its leanness and low tensile strength.

The underlying clay is less sandy and feels far more plastic. It contains a few small mica scales. It slakes moderately fast to grains of small size, and is not a very dense clay. The following description applies to the part of this lower clay (6 to 8 feet thick) exposed and used in the pits at Roanoke Rapids, and here designated the middle clay (sample No. 2):

It required 26.5% of water to make a workable mass, which was highly plastic. This mud shrunk 10% in drying and an additional 5% in burning, giving a total shrinkage of 15%. Air-dried briquettes made from this paste exhibited an average tensile strength of 151 pounds per square inch and a maximum of 168 pounds per square inch. Incipient fusion occurs at 1900° F., vitrification at 2050° F., and viscosity at 2250° F. The clay burns to a red body, much smoother than the preceding sample.

The increased plasticity is very noticeable, and due no doubt in part to the smaller quantity of sand present and perhaps greater fineness of the grains.

The following is the composition of the clay:

*Analysis of the middle Brick-clay (No. 2), Roanoke Rapids.*

Moisture .....	2.45
Silica (total) .....	65.58
Alumina .....	17.04
Ferric oxide .....	5.76
Lime .....	.72
Magnesia .....	.28

Clay substance .....	58.55
Free sand .....	40.90
Total fluxes .....	3.81
Specific gravity .....	2.43

The second cut is at the 100-mile post, and the clay shows nine feet of thickness.

Here, again, the clay (No. 17) is very fine-grained and homogeneous, but not quite so gritty as the preceding. It slakes just the same, and required 32% of water to make a workable but rather lean paste, which shrunk 8% in drying and 6% in burning, or a total of 14%. The air-dried briquettes had an average tensile strength of 24 lbs. per square inch and a maximum of 29 lbs. per square inch. Incipient fusion occurred at 1950° F., vitrification at 2150° F., and viscosity at 2350° F. The clay burns to a smooth, red body. Its composition is:

*Analysis of Brick-clay (No. 17), C. F. & Y. V. R. R., at 100 mile post.*

Moisture .....	1.35
Silica (total) .....	50.68
Alumina .....	32.51
Ferric oxide .....	3.06
Lime .....	.30
Magnesia .....	.02
Alkalies .....	.58
Water (loss on ignition) .....	11.08
Total .....	99.58
Clay substance .....	83.43
Free sand .....	16.15
Total fluxes .....	3.96
Specific gravity .....	2.53

The third cut along the railroad is a half mile southeast of Spout Springs and shows fully 12 feet of this clay; while a fourth exposure of it is in the cut just northwest of Spout Springs station (Plate XII, fig. 2).

The clay exposed in this last mentioned cut possesses the same homogeneous, tough, fine-grained character as those just described. A sample (No. 18) tested from this place slaked quickly and, when mixed with 35% of water, gave a workable, lean, smooth mass that shrunk 9% in drying and 8% in burning, a total shrinkage of 17%. The air-dried briquettes made from this paste had an exceedingly low tensile strength of 19 lbs. per square inch on the average with a maximum of 25 lbs. per square inch. Incipient fusion occurred at 2000° F., vitrification at 2200° F., and viscosity at 2400°. The clay burns to a red-gray body. The following is the composition of this clay:



FIG. 1.—BRICKWORKS OF CARTER AND SHEPARD, BETHANIA.  
(See page 111.)



FIG. 2.—CLAY DEPOSIT IN RAILWAY CUT, SPOUT SPRINGS, C. F. & Y. V. RAILROAD.





*Analysis of Clay (No. 18), C. F. & Y. V. R. R., Spout Springs station.*

Moisture .....	1.05
Silica (total) .....	53.65
Alumina .....	28.66
Ferric oxide .....	4.50
Lime .....	.10
Magnesia .....	1.35
Alkalies .....	.29
Water (loss on ignition) .....	10.79
Total .....	100.39
Clay substance .....	73.77
Free sand .....	26.65
Total fluxes .....	6.24
Specific gravity .....	2.41

**CLAY IN JACKSON COUNTY.**

SYLVA.—Along the road south of Sylva and three-quarters of a mile the kaolin washing works is considerable outcropping of gray clay (No. 55) with much quartz. There is also an abundance of mica in it. The clay which has been experimented with in the hopes that ball-clay might be obtained from it by washing, contains too much iron oxide. Its chief application lies in the manufacture of pressed ware to mix with a more plastic clay for vitrified wares, such as pipes or possibly paving brick.

The clay, which varies from coarse to fine, contains abundant grains of mica as well as scales of mica. It slakes slowly to irregular grains. Absorption of 28% of water gave a tough but stiff mass, which is gritty and plastic. The shrinkage in drying was 9% and in firing 5%, giving a total shrinkage of 14%. The average tensile strength of the air-dried briquettes was 58 lbs. per square inch, with a maximum of 67 lbs. Incipient fusion occurred at 2100° F., vitrification at 3000° F., and viscosity at 2500° F.

The clay burns red. Its composition is as follows:

*Analysis of Brick-clay (No. 55), near Sylva.*

Moisture .....	.45
Silica (total) .....	66.70
Alumina .....	19.75
Ferric oxide .....	3.25
Lime .....	.45
Magnesia .....	.16
Alkalies .....	2.12
Water (loss on ignition) .....	6.65
Total .....	90.53

Clay substance .....	47.28
Free sand .....	52.25
Total fluxes .....	6.08
Specific gravity .....	2.59

**CLAY IN MARTIN COUNTY.**

NEAR WILLIAMSTON.—Two samples of residual clay from this locality were submitted to the Geological Survey for testing. The first (No. 66) was a moderately coarse-grained clay which slaked easily to irregular grains. The addition of 40% of water was required to give a workable mass that to the feel was lean and gritty. This mud shrunk 13% in drying and 3% in burning, giving a total shrinkage of 16%. Care had to be exercised in drying to prevent it from cracking. The average tensile strength of the air-dried briquettes was 67 lbs. per square inch, while the maximum was 78 lbs. Incipient fusion occurs at 2000° F., vitrification at 2150° F., and viscosity at 2300° F. The clay burns red at incipient fusion, but above that the color deepens rapidly.

The second sample was similar in appearance to the first one, and, like it, slaked easily to its component grains. The addition of 29% of water gave a workable but lean, sticky mass, which shrunk 10% in drying and 2% in burning, giving a total shrinkage of 12%. The air-dried briquettes had an average tensile strength of 74 lbs. per square inch with a maximum of 100 lbs. Incipient fusion occurred at 2000° F., vitrification at 2150° F., and viscosity at 2200° F.

The clay burns red at 2000° F., but the color becomes much deeper with harder firing.

This clay cracks less than the previous one in drying, for the shrinkage is less.

Both these clays illustrate the lean character and low-binding qualities of some clays, both sedimentary and residual. Their porous nature and avidity for water cause them to soak up large quantities of it, and the consequent expulsion of this water brings about excessive shrinkage and necessitates very slow drying. The only remedy in such cases is the admixture with these lean, porous clays of other clays that are more compact and have better binding qualities.

**CLAY IN MECKLENBURG COUNTY.**

NEAR CHARLOTTE.—The region in the vicinity of Charlotte is underlain by sedimentary clays in the hollows, and residual clays on the hills. While those in the hollows are largely composed of the wash from the hills, still, on account of the sorting and elimination of coarse particles which follow as a result of the washing, the lowland deposits are smoother and more plastic.

One of the latter class is near *D. K. Cecil's yard* on Trade street at the east edge of the town.

The section of this clay bank shows the following:

Loam (soil) .....	12-18 inches.
Clay .....	8 feet.
Sand .....	—

The clay is gray, mottled with iron stains, fine-grained, fairly smooth. There is no mica apparent. It slakes quickly.

The addition of 25.8% of water gave a moderately plastic paste with somewhat gritty feel. This paste shrunk 6% in drying and 6% in burning, giving a total shrinkage of 12%. The average tensile strength of air-dried briquettes was 88 lbs. per square inch with a maximum strength of 95 lbs. per square inch.

Incipient fusion occurs at 1850° F., vitrification at 2050° F., and viscosity at 2250° F.

The clay burns to a red, fairly smooth body. Its composition is as follows:

*Analysis of D. K. Cecil's Brick-clay (No. 39), Charlotte.*

Moisture .....	1.35
Silica (total) .....	68.35
Alumina .....	13.13
Ferric oxide .....	6.87
Lime .....	2.10
Magnesia .....	.32
Alkalies .....	2.86
Water (loss on ignition) .....	5.20
Total .....	100.18
Clay substance .....	38.73
Free sand .....	61.45
Total fluxes .....	12.15
Specific gravity .....	2.68

Mr. Cecil uses the clay for the manufacture of common brick. The clay is molded in an auger side-cut machine, dried on pallets and burned in scove kilns. The product is usually a hard, dense brick.

At *Houser's yard*, one-quarter mile from Cecil's, there is a similar deposit of sedimentary clay. It contains an abundance of small quartz grains. The bricks are barely burned to incipient fusion. Houser's plant includes a pair of rolls, Brewer side-cut machine, and pallet racks.

The clay from this yard was not tested. It is situated along the same stream as Cecil's deposit.

At *F. M. Sassamon's brickyard*, two miles northwest of Charlotte,

the clay lies in a hollow and covers a number of acres. Its exact thickness is not known, but it is not less than six feet. A sample of this clay was examined and found to be a somewhat coarse-grained, porous clay. It slakes moderately fast to fine aluminous mud and granules. The addition of 35% of water gave a plastic mass, which shrunk 13.3% in drying and 8% in burning, giving a total shrinkage of 21.3%. The drying could not be hurried, as otherwise cracking resulted. The average tensile strength of the air-dried briquettes was 105 lbs. per square inch with a maximum of 125 lbs.

Incipient fusion occurred at 1950° F., vitrification at 2100° F., and viscosity at 2250° F. The clay burns red.

Its composition is as follows:

*Analysis of F. M. Sassamon's Brick clay (No. 42), Charlotte.*

Moisture .....	1.27
Silica (total) .....	65.95
Alumina .....	14.67
Ferric oxide .....	7.61
Lime .....	2.57
Magnesia .....	.25
Alkalies .....	2.55
Water (loss on ignition) .....	5.52
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Total .....	100.39
Clay substance .....	43.84
Free sand .....	56.45
Fluxes .....	12.98
Specific gravity .....	2.60

*Shuman* operates a deposit (No. 41) just north of Charlotte, which is a mixture of sedimentary clay and residuum. It is about 9 feet thick as exposed, and varies from a sandy clay to a fat, tough one.

Most of it is coarse-grained, gritty, and slakes slowly but completely. The clay required the addition of 35% of water to give a workable, though lean mass. Its porous nature permitted rapid drying, and it shrunk 5% in doing so. The shrinkage in burning was 4%, giving a total shrinkage of 9%. Air-dried briquettes had an average tensile strength of 26 lbs. per square inch and a maximum of 28 lbs. Incipient fusion occurred at 2100° F., vitrification at 2200° F., and viscosity at 2300° F. The clay burns to a reddish brick.

The composition of it is as follows:

*Analysis of F. W. Shuman's Brick-clay (No. 41), Charlotte.*

Moisture .....	7.10
Silica .....	59.15
Alumina .....	18.36

Ferric oxide .....	6.04
Lime .....	.20
Magnesia .....	.34
Alkalies .....	1.72
Water (loss on ignition) .....	7.47
Total .....	100.38
Free sand .....	39.50
Total fluxes .....	8.30
Specific gravity .....	2.44

*J. Asbury* has a brickyard about one and a half miles north of the town. The section at the clay bank shows four feet of red clay (sample No. 62) and under this six feet of very plastic blue clay. The addition of 25% of water gave a workable paste of good plasticity.

This paste shrank 7% in drying and 5% in burning. The average tensile strength of the air-dried briquettes was 60 lbs. per square inch with a maximum of 72 lbs. per square inch. Incipient fusion occurred at 1900° F., vitrification at 2100° F., and viscosity at 2300° F.

The clay burns red. Its analysis shows the following:

*Analysis of J. Asbury's upper red Brick-clay (No. 62), Charlotte.*

Moisture .....	.63
Silica (total) .....	60.33
Alumina .....	18.57
Ferric oxide .....	10.03
Lime .....	.20
Magnesia .....	.14
Alkalies .....	.55
Water (loss on ignition) .....	7.83
Total .....	98.28
Clay substance .....	56.23
Free sand .....	42.05
Total fluxes .....	10.92
Specific gravity .....	2.60

**CLAY IN RICHMOND COUNTY.**

**NEAR ROCKINGHAM.**—A red, coarse-grained, sedimentary clay (No. 23) occurs at Roberdell, four miles north of Rockingham. The upper portion of the deposit is somewhat sandy. In practice the bricks seem to shrink considerably in burning and also to crack, but they burn to a deep red color. The deposit is owned by R. L. Steele.

A sample of this clay slaked slowly to grains  $\frac{1}{8}$  to  $\frac{1}{4}$  in. diameter. It required 26% of water to make a workable paste which shrunk 6% in drying and 8% in burning, making a total shrinkage of 14%. It required slow heating to avoid cracking. The average tensile strength

of air-dried briquettes made from this paste was 133 lbs. per square inch with a maximum of 154 lbs. Incipient fusion occurs at 2000° F., vitrification at 2200° F., viscosity at 2400° F. The clay burns to a deep red. It is not fine or smooth enough to be used for pottery. The composition of the clay is as follows:

*Analysis of Brick clay (No. 23), 4 miles N. of Rockingham.*

Moisture .....	1.98
Silica (total) .....	59.59
Alumina .....	22.07
Ferric oxide .....	4.27
Lime .....	.65
Magnesia .....	.49
Alkalies .....	2.70
Water (loss on ignition) .....	7.53
Total .....	99.28
Clay substance .....	51.63
Free sand .....	47.65
Fluxes .....	8.11
Specific gravity .....	2.54

**CLAY IN ROBESON COUNTY.**

**NEAR RED SPRINGS.**—Five or six brickyards have been in operation at this locality for some years. The flat, wooded region around the town is underlain by abundance of yellowish, coarse-grained, sandy clay of extreme leanness. The abundant sand grains are nearly all pure quartz.

The poor quality of this material is evident on sight, but a sample (No. 19) was tested in order to demonstrate this fact, for there is a tendency among many small manufacturers to use very sandy clay, as it molds easier.

The examination showed it to be a porous, coarse clay, slaking fairly fast in water. It required 17% of water to make a workable mass which was extremely lean. This paste shrank 8.8% in drying and 12.8% in burning, giving a total shrinkage of 20.6%. Air-dried briquettes had an average tensile strength of 41 lbs. per square inch and a maximum of 51 lbs. Incipient fusion occurred at 2100° F., vitrification at 2250° F., viscosity at 2400° F. At 2100° F. it burns red, but is still porous and weak.

The composition of the clay is as follows:

*Analysis of Brick-clay (No. 19), Red Springs.*

Moisture .....	1.09
Silica (total) .....	78.16
Alumina .....	8.28
Ferric oxide .....	4.09
Lime .....	.40

Magnesia .....	.22
Alkalies .....	2.91
Water (loss on ignition) .....	4.14
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Total .....	99.27
Clay substance .....	15.22
Free sand .....	74.05
Total fluxes .....	7.62
Specific gravity .....	2.60

The chemical analysis indicates the large percentage of sand in the clay, and the quantity and coarseness of this sand makes the clay too m. On account of this very high percentage of sand in the clay considerable heat is required to make a hard brick of it.

None of the clay pits at Red Springs are deep, and it is not known whether the clay increases with depth, but if it does the product would be of much better quality by using it.

#### CLAY IN ROWAN COUNTY.

NEAR SALISBURY.—Half a mile south of the station is an area of swamp land underlain by considerable clay, mostly of a plastic nature. The section shows 6 feet of clay underlain by sand, and the tract is about an eighth of a mile long. There are occasional iron streaks in the clay, but these are mostly confined to sandy spots. A sample of this clay (No. 48) which was tested showed it to be medium-grained with considerable grittiness. It slaked slowly and required the addition of 28% of water to give a workable mixture which was very plastic. The mass shrunk 8.5% in drying and 5.5% in burning, giving a total shrinkage of 14%. The average tensile strength of air-dried briquettes was 129 lbs. per square inch with a maximum of 144 lbs. Incipient fusion occurs at 1850° F., vitrification at 2050° F., and viscosity at 2500° F.

The clay burns to a red color. Its composition is as follows:

##### *Analysis of Brick-clay (No. 48), south side of Salisbury.*

Moisture .....	1.91
Silica (total) .....	69.89
Alumina .....	15.31
Ferric oxide .....	4.39
Lime .....	.55
Magnesia .....	.16
Alkalies .....	.70
Water (loss on ignition) .....	6.37
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Total .....	99.28
Clay substance .....	47.38
Free sand .....	51.90
Total fluxes .....	5.80

This clay has been used at D. K. Cecil's brickyard for five years. The clay receives no tempering, but is charged directly into a small auger machine with a three-stream die. The bricks are dried in the sun and burned in scove kilns.

The quality of the brick admits of much improvement, and the quality of the clay warrants it.

#### CLAY IN SURRY COUNTY.

NEAR ELKIN.—An opening has been made one mile west of town along the railroad and on the property of the Pomona Sewer-pipe Co., and exposes the same yellowish clay as that noted at Wilkesboro. The clay is 8-10 feet deep and underlain by sand and coarse pebbles.

The clay itself (No. 38a) is fine-grained and contains numerous small mica scales and fine grit. It slakes somewhat slowly to its component grains. The addition of 16% of water gave a workable but somewhat lean mud, which shrank 7% in drying and 9% in burning. The average tensile strength of the air-dried briquettes was 69 lbs. per square inch and the maximum was 73 lbs.

Incipient fusion occurred at 1900° F., vitrification at 2100° F., viscosity at 2300° F. The clay burns red and gets very deep red or brown on vitrifying.

The analysis of it yielded the following:

##### *Analysis of Brick-clay (No. 38a), Pomona Co.'s bank, Elkin.*

Moisture .....	.90
Silica (total) .....	59.48
Alumina .....	19.24
Ferric oxide .....	8.26
Lime .....	.60
Magnesia .....	1.01
Alkalies .....	3.76
Water (loss on ignition).....	6.41
<b>Total .....</b>	<b>99.66</b>
Clay substance .....	49.21
Free sand .....	50.35
Total fluxes .....	13.53
Specific gravity .....	2.59

Mixed with some more plastic clay, such as that used for sewer-pipe at Pomona, this clay might possibly be used for the manufacture of paving brick.

There are numerous points between Elkin and North Wilkesboro where the cutting of gullies in the terrace has exposed this yellow clay.

The clay used at the brickyards just east and west of Elkin is red-



ual material of uncertain character and not associated with that down in the valley bottom.

While these yellow clays of the lowlands would doubtless make a good smooth building brick by the soft-mud process, it is doubtful if they would work in an auger machine, and probably refuse to issue from the die without tearing, for there is little bond between the clay particles. In mixing, it also shows slight tendency by itself towards the development of a laminated structure.

#### CLAY IN UNION COUNTY.

NEAR MONROE.—The lowlands southwest of the depot are underlain by an abundance of blue clay, and though only about 6 feet deep, still it covers a considerable area. As the creek which flows through the lowland is approached the clay becomes more sandy.

A sample of this clay (No. 40) was found to be fairly smooth and slaked slowly but rather completely. It required the addition of 23% of water to produce a workable mass that was very plastic and that shrank 6% in drying and 3% in burning, giving a total shrinkage of 9%. Incipient fusion occurred at 1950° F., vitrification at 2150° F., and viscosity at 2350° F. The clay burns red, but underburning produces a yellowish red.

For a plastic clay the shrinkage is quite low.

The average tensile strength of the air-dried briquettes was 124 lbs. per square inch with a maximum of 148 lbs. per square inch.

It is probable that some of the finer portions of this clay bed could be used for the lower grades of stoneware.

The composition of the clay is as follows, the sample (No. 40) coming from J. T. Shute's clay bank:

#### *Analysis of Brick-clay (No. 40), Shute's clay bank, Monroe.*

Moisture .....	1.65
Silica (total) .....	76.60
Alumina .....	9.98
Ferric oxide .....	4.46
Lime .....	.30
Magnesia .....	.27
Alkalies .....	2.25
Water (loss on ignition) .....	4.30
Total .....	99.81
Clay substance .....	34.26
Free sand .....	65.55
Total fluxes .....	7.28

The clay contains a small amount of organic matter and is a good illustration of the combination of low alumina and marked plasticity.

J. T. Shute manufactures common brick from the clay at 1 The clay makes a very fair product, but has to be burned careful

The bricks are molded in a Brewer auger machine with vertical cylinder attached.

#### CLAY IN WAKE COUNTY.

NEAR RALEIGH.—Much clay of very plastic nature under bottom lands north and east of the city. It has thus far been only for building brick, although promising experiments have made looking towards its utilization for the coarser grades of A small deposit of considerable plasticity underlies the low between Caraleigh Mills and the phosphate mill southeast of This deposit is not nearly so extensive, however, as that north town in the lowland along the Neuse river.

The clay used at the penitentiary is obtained from the southeast of the city. The upper two feet are a yellowish sand but under this is a much fatter gray clay possessing considerable plasticity to the feel, and frequently comparatively free from grit in form of coarse sand grains. A small amount of organic matter is present. It is a tough, fairly compact clay which slakes rather grains and granules. It required the addition of 25% of water to workable mass, which shrunk 9.3% in drying and 4% in burning, total shrinkage of 13.3%. Air-dried briquettes made from this had an average tensile strength of 123 lbs. per square inch and minimum tensile strength of 144 lbs. per square inch. Incipient vitrification occurred at 2000° F., vitrification at 2150° F., and viscosity at 2 The clay burns to a red, which increases in depth of color with clay is burned to vitrification. The composition of this clay is given by the following:

#### *Analysis of Brick-clay (No. 23), Penitentiary Yard, Raleigh.*

Moisture .....	1.60
Silica (total) .....	70.03
Alumina .....	15.64
Ferric oxide .....	2.88
Lime .....	.80
Magnesia .....	.57
Alkalies .....	1.47
Water (loss on ignition) .....	6.37
Total .....	99.36
Free sand .....	54.55
Clay substance .....	44.81
Total fluxes .....	5.72
Specific gravity .....	2.54

The low percentage of total fluxes accounts partly for the fusion point being 2300°.

It is probable that some of the smoother portions of this clay deposit would work very well for common stoneware.

The clay underlying A. H. Green's land on the north side of the river is less gritty.

The clay-working industry around Raleigh is confined to the manufacture of common brick. These are made by the Caraleigh Mills Company and the North Carolina State Penitentiary. Both used hand-molds and dry the bricks in the sun and burn them in up-draft, open-top kilns. Considering the method of molding, the clay makes a very good red building brick. Steam-power machinery would no doubt greatly increase the value of the product. Re-pressing has been tried with considerable success, and brick thus treated were used in the governor's mansion at Raleigh.

#### CLAY IN WAYNE COUNTY.

NEAR GOLDSBORO.—There are extensive beds of sedimentary clay underlying the lowlands southeast of the town. At the *Goldsboro Brick and Tile Company*, or Grant's yard, one mile southwest of Goldsboro, quite a large surface has been worked over in obtaining its clay, in order to use the clay at the surface, which is far more sandy but of good plasticity. The exact depth of the clay is not known.

A track runs along the central portion of the excavation, and the clay is dug by means of scrapers and brought to cars on the track. These cars are hauled to the foot of an incline and drawn up by cable to the second floor of the works, where the clay is discharged. It passes first through a pair of rolls and then to the pugmill, from which it is discharged into a Kell's auger machine. The brick are side-cut, and the cutting table is operated by hand power. Ten brick are cut at a time and discharged from the cutting table on to a pallet. The bricks are carried directly to the drying chambers. These consist of a series of cupboards, across which runs a series of parallel steam-pipes, which serve as a shelving. The pallets are shoved endwise into each chamber. In the practice of this method a considerable per cent. of the brick may be lost when, in pushing the pallet into the chamber, the "off-bearer" pushes against the end brick instead of the pallet and crushes the former all out of shape. The drying requires three days when heat is applied during the daytime only. The yard is also equipped with pallet racks.

Burning is done in up-draft kilns with a capacity of about 200,000 each. The bricks are burned to a light red.

The upper part of the clay consists of tough, light-blue plastic clay

This clay has been used at D. K. Cecil's brickyard for five years. The clay receives no tempering, but is charged directly into a small auger machine with a three-stream die. The bricks are dried in the sun and burned in scove kilns.

The quality of the brick admits of much improvement, and the quality of the clay warrants it.

#### CLAY IN SURRY COUNTY.

NEAR ELKIN.—An opening has been made one mile west of town along the railroad and on the property of the Pomona Sewer-pipe Co., and exposes the same yellowish clay as that noted at Wilkesboro. The clay is 8-10 feet deep and underlain by sand and coarse pebbles.

The clay itself (No. 38a) is fine-grained and contains numerous small mica scales and fine grit. It slakes somewhat slowly to its component grains. The addition of 16% of water gave a workable but somewhat lean mud, which shrank 7% in drying and 9% in burning. The average tensile strength of the air-dried briquettes was 69 lbs. per square inch and the maximum was 73 lbs.

Incipient fusion occurred at 1900° F., vitrification at 2100° F., viscosity at 2300° F. The clay burns red and gets very deep red or brown on vitrifying.

The analysis of it yielded the following:

##### *Analysis of Brick-clay (No. 38a), Pomona Co.'s bank, Elkin.*

Molsture .....	.90
Silica (total) .....	59.48
Alumina .....	19.24
Ferric oxide .....	8.26
Lime .....	.00
Magnesia .....	1.01
Alkalies .....	3.76
Water (loss on ignition).....	6.41
Total .....	99.66
Clay substance .....	49.21
Free sand .....	50.35
Total fluxes .....	13.53
Specific gravity .....	2.59

Mixed with some more plastic clay, such as that used for sewer-pipe at Pomona, this clay might possibly be used for the manufacture of paving brick.

There are numerous points between Elkin and North Wilkesboro where the cutting of gullies in the terrace has exposed this yellow clay.

The clay used at the brickyards just east and west of Elkin is residual.

ual material of uncertain character and not associated with that down in the valley bottom.

While these yellow clays of the lowlands would doubtless make a good smooth building brick by the soft-mud process, it is doubtful if they would work in an auger machine, and probably refuse to issue from the die without tearing, for there is little bond between the clay particles. In mixing, it also shows slight tendency by itself towards the development of a laminated structure.

#### CLAY IN UNION COUNTY.

NEAR MONROE.—The lowlands southwest of the depot are underlain by an abundance of blue clay, and though only about 6 feet deep, still it covers a considerable area. As the creek which flows through the lowland is approached the clay becomes more sandy.

A sample of this clay (No. 40) was found to be fairly smooth and slaked slowly but rather completely. It required the addition of 23% of water to produce a workable mass that was very plastic and that shrank 6% in drying and 3% in burning, giving a total shrinkage of 9%. Incipient fusion occurred at 1950° F., vitrification at 2150° F., and viscosity at 2350° F. The clay burns red, but underburning produces a yellowish red.

For a plastic clay the shrinkage is quite low.

The average tensile strength of the air-dried briquettes was 124 lbs. per square inch with a maximum of 148 lbs. per square inch.

It is probable that some of the finer portions of this clay bed could be used for the lower grades of stoneware.

The composition of the clay is as follows, the sample (No. 40) coming from J. T. Shute's clay bank:

#### *Analysis of Brick-clay (No. 40), Shute's clay bank, Monroe.*

Moisture .....	1.65
Silica (total) .....	76.60
Alumina .....	9.98
Ferric oxide .....	4.46
Lime .....	.30
Magnesia .....	.27
Alkalies .....	2.25
Water (loss on ignition) .....	4.30
Total .....	99.81
Clay substance .....	34.26
Free sand .....	65.55
Total fluxes .....	7.28

The clay contains a small amount of organic matter and is a good illustration of the combination of low alumina and marked plasticity.

*Analysis of Weil's Brick-clay (No. 8), Goldsboro.*

Moisture .....	1.85
Silica (total) .....	67.90
Alumina .....	18.74
Ferric oxide .....	3.16
Lime .....	.40
Magnesia .....	.45
Alkalies .....	1.85
Water (loss on ignition) .....	6.03
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Total .....	100.38
Clay substance .....	46.23
Total fluxes .....	5.86
Free sand .....	54.15
Specific gravity .....	2.57

**CLAY IN WILKES COUNTY.**

NEAR WILKESBORO.—The valley of the Yadkin river at this place is nearly three-quarters of a mile wide, and its broad, flat bottom underlain by an abundance of clay.

At *D. Smoak's yard*, on the south side of the river just west of the iron bridge, the clay is said to be 13 feet thick and to be underlain by gravel and sand. As the river is approached, the surface sand increases in depth. The clay is claimed to improve greatly with the depth. A sample (No. 37) was taken from the bottom of the deposit and (No. 36) representing the average material now used.

The latter (No. 36) is a fine-grained, yellowish clay with numerous very small mica scales. It slakes quite rapidly and completely to fine grains. The addition of 25% of water gave a workable but lean paste. This paste shrunk 5% in drying and 10% in burning, giving a shrinkage of 15%. The average tensile strength of the air-dried quettes was 74 lbs. per square inch with a maximum of 76 lbs. per square inch.

Incipient fusion occurs at 1900° F., vitrification at 2100° F., and viscosity at 2300° F.

At 2100° the clay burns to a good red, but above this temperature it darkens rapidly.

The composition of this clay is as follows:

*Analysis of Smoak's Brick-clay (No. 36), Wilkesboro.*

Moisture .....	1.03
Silica (total) .....	53.75
Alumina .....	24.91
Ferric oxide .....	7.99
Lime .....	.70
Magnesia .....	1.12

The low percentage of total fluxes accounts partly for the fusion point being 2300°.

It is probable that some of the smoother portions of this clay deposit would work very well for common stoneware.

The clay underlying A. H. Green's land on the north side of the river is less gritty.

The clay-working industry around Raleigh is confined to the manufacture of common brick. These are made by the Caraleigh Mills Company and the North Carolina State Penitentiary. Both used hand-molds and dry the bricks in the sun and burn them in up-draft, open-top kilns. Considering the method of molding, the clay makes a very good red building brick. Steam-power machinery would no doubt greatly increase the value of the product. Re-pressing has been tried with considerable success, and brick thus treated were used in the governor's mansion at Raleigh.

#### CLAY IN WAYNE COUNTY.

NEAR GOLDSBORO.—There are extensive beds of sedimentary clay underlying the lowlands southeast of the town. At the *Goldsboro Brick and Tile Company*, or Grant's yard, one mile southwest of Goldsboro, quite a large surface has been worked over in obtaining its clay, in order to use the clay at the surface, which is far more sandy but of good plasticity. The exact depth of the clay is not known.

A track runs along the central portion of the excavation, and the clay is dug by means of scrapers and brought to cars on the track. These cars are hauled to the foot of an incline and drawn up by cable to the second floor of the works, where the clay is discharged. It passes first through a pair of rolls and then to the pugmill, from which it is discharged into a Kell's auger machine. The brick are side-cut, and the cutting table is operated by hand power. Ten brick are cut at a time and discharged from the cutting table on to a pallet. The bricks are carried directly to the drying chambers. These consist of a series of cupboards, across which runs a series of parallel steam-pipes, which serve as a shelving. The pallets are shoved endwise into each chamber. In the practice of this method a considerable per cent. of the brick may be lost when, in pushing the pallet into the chamber, the "off-bearer" pushes against the end brick instead of the pallet and crushes the former all out of shape. The drying requires three days when heat is applied during the daytime only. The yard is also equipped with pallet racks.

Burning is done in up-draft kilns with a capacity of about 200,000 each. The bricks are burned to a light red.

The upper part of the clay consists of tough, light-blue plastic clay

with much intermixed sand. The use of the rolls is supposed to break up these lighter-colored lumps of clay, but it does not always do so entirely, as can be seen from an inspection of the burned brick, the lighter-colored lumps of the clay occasionally showing within. A wet pan would probably give better results. The mixture of the sandy and tough clay gives the best results and makes a good brick.

A sample of this clay was tested. It was a coarse to fine-grained clay (No. 7) that slaked irregularly. The addition of 33 per cent. of water gave a fairly plastic and somewhat tough mass, which shrunk 8% in drying and 6% in burning, giving a total shrinkage of 14%. The air-dried briquettes had an average tensile strength of 65 lbs. per square inch and a maximum tensile strength of 74 lbs. per square inch. Incipient fusion occurs at 1900° F., vitrification at 2100° F., and viscosity at 2300° F.

This kind of clay should be thoroughly mixed, and when so treated it burns to a uniform attractive red, but if the clay be not well mixed the lumps of tougher clay are plainly seen if the temperature is raised rapidly so that the iron in them does not get a chance to become thoroughly oxidized. The composition of this clay mixture is as follows:

*Analysis of Grant's Brick-clay (No. 7), Goldsboro.*

Moisture .....	1.58
Silica (total) .....	66.05
Alumina .....	17.81
Ferric oxide .....	6.69
Lime .....	.30
Magnesia .....	.25
Alkalies .....	1.04
Water (loss on ignition) .....	6.32
Total .....	100.04
Clay substance .....	51.47
Total fluxes .....	7.76
Free sand .....	48.05
Specific gravity .....	2.53

Near the factory of the Goldsboro Brick and Tile Company is a considerable quantity of tough clay which is called "fire-clay," but which is not a true fire-clay as that term is generally used. This clay simply requires a little more heat in burning the brick than the clay usually employed.

A sample of this "fire-clay" showed it to be a tough, plastic, fine grained clay with scattered scales of mica. It slakes moderately fast to a mixture of fine powder and small angular quartz grains. The addition of 25% of water gave a plastic, workable paste that shrunk 8.5% in



drying and an additional 5% in burning, giving a total shrinkage of 13.5%. The air-dried briquettes made from this paste had an average tensile strength of 107 lbs. per square inch and a maximum of 125 lbs. per square inch. Incipient fusion occurs at 1950° F., vitrification at 2150° F., and viscosity at 2300° F. The clay burns to a deep red, tough, dense body, and might be worked for stoneware.

The following analysis shows its composition:

*Analysis of Grant's "Fire-clay" (No. 9), Goldsboro.*

Moisture .....	1.12
Silica (total) .....	65.95
Alumina .....	13.51
Ferric oxide .....	4.64
Lime .....	.35
Magnesia .....	.36
Alkalies .....	2.82
Water (loss on ignition) .....	11.58
<hr/>	
Total .....	100.33
Clay substance .....	49.63
Total fluxes .....	8.17
Free sand .....	50.70
Specific gravity .....	2.55

On account of the high percentage of combined water the clay had to be heated very slowly to prevent cracking.

*H. Weil & Bros.' yard* and clay bank are about a mile and a half southwest of Goldsboro. Their clay deposit, which is an extension of that of the Goldsboro Brick & Tile Co., contains a considerable quantity of plastic clay. This is 8 feet thick in places, and towards the surface becomes mixed with sand. The clay is molded by hand and pugged in a vertical mill operated by horse-power. The water-smoking and burning is done in the rather short time of five days.

A sample of the plastic clay (No. 8) tested showed it to be moderately fine with considerable grit and mica scales. The clay is somewhat porous but tough, and slakes slowly to irregular grains. The addition of 25% of water gave a workable mixture of fair plasticity. It shrunk 8.3% in drying and 3% in burning, giving a total shrinkage of 11.3%. The air-dried briquettes made from the worked-up paste had an average tensile strength of 85 lbs. per square inch and a maximum strength of 102 lbs. per square inch. Incipient fusion occurs at 1900° F., vitrification at 2100° F., and viscosity at 2300° F.

The clay burns to a red color. Underburning and imperfect oxidation make the brick grayish-red or brown, and porous.

The composition of the clay is as follows:

The air-dried briquettes made from this paste had an average tensile strength of 138 lbs. per square inch and a maximum of 155 lbs. per square inch.

Incipient fusion occurred at 1950° F., vitrification at 2100° F., and viscosity at 2250° F. The color of the burned clay was red. Its composition, as shown by the following analysis, corresponds closely with that of the preceding sample.

*Analysis of Lucas' Brick clay (No. 6), E of Wilson.*

Molsture .....	1.68
Silica (total) .....	68.28
Alumina .....	13.59
Ferric oxide .....	5.06
Lime .....	.15
Magnesia .....	.47
Alkalies .....	2.82
Water (loss on ignition) .....	6.00
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Total .....	98.65
Clay substance .....	43.09
Total fluxes .....	7.69
Free sand .....	53.55
Specific gravity .....	2.52

Other clays of the same nature are exposed for some distance along the railroad track north and south of Wilson. A number of buff brick have been made from a deposit lying south of the town.

COMPARISON OF CLAYS FROM WILSON AND WAYNE COUNTIES.

The clays at Wilson and Goldsboro are, as has been previously stated, of sedimentary nature and somewhat similar in character.

Experiments and actual practice point to the fact that very different results can be obtained from these clays by the use of different methods. Hand-molding, improper tempering and hurried burning give a poor, porous, badly-colored brick. Steam power machines give a much smoother brick. Auger machines were tried by some and given up in disgust, but the machines used had the shortest possible pugmill and the clay received no other tempering. When rolls are used they seldom do more than flatten out the tough lumps of clay. In a cheap auger machine the die is often improperly constructed, and laminations of the worst kind may be produced in the brick. If the brick is not thoroughly burned, these laminations will result in the shelling off of fragments from the brick.

Alkalies .....	2.94
Water (loss on ignition) .....	7.60
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Total .....	100.04
Clay substance .....	54.04
Total fluxes .....	12.75
Free sand .....	46.00
Specific gravity .....	2.63

The bottom clay (No. 37) at Smoak's brickyard is also a fine-grained, yellowish-brown clay with abundant fine grit and small mica scales. It slakes rather quickly and completely to its component grains. The clay required 24% of water to make a workable paste, which was somewhat lean.

This paste shrunk 6% in drying and 9% in burning, giving a total shrinkage of 15%. The average tensile strength of the air-dried briquettes was 71 lbs. per square inch with a maximum of 84 lbs.

Incipient fusion occurred at 1900° F., vitrification at 2100° F., and viscosity at 2300° F.

The clay burns to a bright red at 1900° F., but this rapidly darkens as the temperature is raised.

The physical characters of this clay are therefore closely similar to that composing upper portions of the deposit.

The composition of this lower clay is as follows:

*Analysis of Smoak's bottom Brick-clay (No. 37), Wilkesboro.*

Molsture .....	2.10
Silica (total) .....	52.25
Alumina .....	20.66
Ferric oxide .....	11.14
Lime .....	.60
Magnesia .....	1.08
Alkalies .....	4.62
Water (loss on ignition) .....	7.45
<hr/>	
Total .....	99.90
Clay substance .....	57.45
Total fluxes .....	17.44
Free sand .....	42.45
Specific gravity .....	2.44

In fluxes this bottom clay runs several per cent. higher than the top and contains less alumina.

This clay and the preceding one described underlie the same terrace as does the pottery clay on the Calvin Cowles land, the two being not more than half a mile apart (see p. 79).

Mr. Smoak uses the yellowish clay for the manufacture of common brick. It is molded by hand, dried in the sun and burned in up-draft, permanent side-wall kilns. The clay makes a good brick, and also yields promising results with re-pressing. Some of the re-pressed brick are to be seen in the bank building at North Wilkesboro.

#### CLAY IN WILSON COUNTY.

NEAR WILSON.—Sedimentary clay occurs in considerable quantity on the east and northeastern edge of the town and is extensively worked. The A. C. L. R. R. passes close to the deposits. At S. Lucas's yard, northeast of the town along the railroad, the section is as follows:

Sandy soil .....	1 ft.
Sand, clayey in spots.....	2 ft.
Sandy clay, red .....	3 ft.
Blue clay .....	3 ft. +

The sandy soil is stripped and a mixture of the remaining portion of the section used. Two openings have been made which show similar sections, but the clay in the southern one is red while that in the northern one is blue. Little iron concretions are not uncommon in the upper portion of the bed, and these in burning produce fused spots.

The red clay (No. 4) is the more sandy of the two. It is a gritty clay, porous and slakes very quickly. The addition of 32% of water gave a lean mass, which shrunk 10% in drying and 5% in burning giving a total shrinkage of 15%. The average tensile strength of air-dried briquettes made from this paste was 84 lbs. per square inch and the maximum 98 lbs. Incipient fusion occurred at 1800° F., vitrification at 1950° F., and viscosity at 2100° F. The clay burns to a red but not very dense body. With hard firing it becomes converted into a black, impervious body in which the individual quartz grains stand out with great distinctness.

The composition of the clay is as follows:

#### *Analysis of red Brick-clay (No. 4), Lucas' Yard, N. E. of Wilson.*

Moisture .....	2.31
Silica (total) .....	62.99
Alumina .....	13.56
Ferric oxide .....	11.52
Ferrous oxide .....	0.33
Lime .....	.10
Magnesia .....	.29
Alkalies .....	2.07
Water (loss on ignition) .....	6.03
Total .....	99.20

The difference between the various makes of kiln consists in the size and shape of the fireplaces, arrangement of flues, slight differences in bag walls, number of stacks, etc. Among the various types may be mentioned those of Eudaly, Graves, etc. Figure 2 of Plate X (p. 101) shows a Eudaly down-draft kiln.

As paving brick soften somewhat in burning to vitrification, it is necessary not to make too many courses, otherwise the lower ones are liable to be crushed out of shape. The water-smoking period varies according to the clay, but 3-4 days is the average, and the burning takes from 4 to 7 days longer. The kiln should be cooled very slowly in order to anneal the brick and give it that great degree of toughness characteristic of all good pavers.

Great care should be taken to avoid any cold air entering the kiln and checking the pavers.

At several localities continuous kilns are used in the burning of paving brick, but while they work fairly well, they are not yet a thoroughly established success.

## CHEMICAL ANALYSES OF NORTH CAROLINA CLAYS.

Field No. used in this Report.	Chemical Laboratory No.	Page in Report where Described.	LOCALITY.	Moisture.	Silica (Total).	Alumina.	Ferric Oxide.	Lime.	Magnesia.	Alkalies.	Water Loss on Ignition.	Miscellaneous.	Total.	Clay substance.	Total Fluxes.	Free Sand.	Remarks.
No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12	No. 13	No. 14				
BLADEN COUNTY.																	
11	502	102	Upper brick-clay, middle of bluff. Prospect Hall .....	4.50	56.13	17.80	5.85	.10	.79	2.45	11.60*	Sulphur.	99.22		7.29	27.18	Not worked.
10	502	103	Middle brick-clay; bluff at Prospect Hall .....	2.80	63.30	15.87	5.48	.27	.21	2.40	8.25*	1.78	100.36	43.06	10.14	57.30	Not worked.
12	509	103	Bottom brick-clay, bluff at Prospect Hall.....	4.26	55.65	20.80	5.11	.30	.64	2.13	9.94*	1.18	100.07	85.03	9.36	15.05	Not worked.
BUNCOMBE COUNTY.																	
59	505	104	Upper clay, Penniman's, Emma.....	1.15	66.27	19.95	3.16	.20	.32	1.85	6.17	Ferrous oxide.	99.74	49.34	6.20	50.40	Brick.
58	578	105	Lower clay, Penniman's, Emma.....	.80	70.66	17.21	3.44	.10	.07	2.45	5.00	.67	99.73	41.71	7.16		
65	572	107	Clay, Fletcher .....	1.10	75.08	13.73	3.47	.30	.17	1.48	4.05		99.98	45.18	5.42		
BURKE COUNTY.																	
51	512	75	Pottery clay, McDowell's, Morganton....	1.68	69.58	14.03	6.41	.40	.27	1.65	5.73		99.75	45.47	8.73	54.28	Not worked.
62	514	107	Brick-clay, McDowell's, Morganton.....	1.80	67.63	16.88	6.50	1.00	1.16	.90	4.78		100.05	39.90	9.56	60.05	
CATAWBA COUNTY.																	
50	557	76	Pottery clay, northwest of Blackburn...	2.08	50.17	28.77	2.88	.05	.22	1.04	14.03*		99.24	73.19	4.19	26.05	Stoneware.
CLEVELAND COUNTY.																	
43	516	81	Eskridge pit, Grover ..	.76	68.28	18.83	2.60	.70	.13	2.29	6.47	Titanic acid.	100.33	46.99	5.72	53.30	Fire-clay.
44	547	82	Powhatan Clay Manufacturing Co's pit, Grover .....	1.29	53.07	29.54	1.27	.15	.14	.87	9.93	Ferrous oxide.	98.54	61.99	4.71	36.55	White pressed brick.
45	571	83	Powhatan Clay Manufacturing Co's pit, ½ mile E. of Grover .....	.95	64.13	22.35	1.95	.10	.22	.99	1.81	1.00	98.48	46.88	5.07	51.00	
46	544	108	Under clay, Cleveland Brick Co., S. of Grover.....	1.18	61.75	23.30	3.34	.27	.25	1.31	7.75	Ferrous oxide.	99.65	60.62	5.67	39.05	Red brick.
47	522	109	Upper clay, Cleveland Brick Co., S. of Grover .....	.63	65.45	20.02	4.18	.25	.20	1.51	6.58	.50	98.91	47.06	6.23	51.45	Red brick.
CUMBERLAND COUNTY.																	
14	503	110	E. A. Poe's pit, ½ mile S. of Fayetteville; average clay .....	2.48	64.93	17.08	5.57	.43	.59	3.85	6.58		101.51	53.13	10.44	45.90	Bricks.
15	509	111	E. A. Poe's pit, ½ mile S. of Fayetteville; "tough" clay .....	3.23	58.17	20.10	7.43	.90	.77	2.60	7.34		100.24	48.09	11.40	52.15	Not worked.

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12	No. 13	No. 14
<b>FORSYTH COUNTY.</b>														
523	112	90	61.39	19.11	5.39	.80	.22	7.75		100.28	53.18	8.13	46.60	Brick and Tile.
524	112	1.85	55.81	20.06	11.79	.33	.16	1.72		100.22	67.44	13.70	31.78	Brick and Tile.
525	113	1.43	61.28	20.83	5.51	.49	.14	0.84		99.27	50.99	6.98	49.05	Not worked.
<b>GASTON COUNTY.</b>														
526	115	1.90	59.27	22.31	6.69	.25	.13	.90		100.45	67.20	7.97	33.25	Brick.
527	116	1.54	56.81	20.62	6.13	.65	.58	4.47		99.50	58.85	11.83	40.65	Brick.
528	116	1.60	69.70	12.87	6.13	.25	.57	2.79		100.19	36.27	12.04	64.92	Brick.
529	84	.98	70.43	17.34	3.16	.25	.22	.70		100.06	48.26	4.66	51.50	Ferrous oxide.
530	89	1.53	58.73	23.94	3.71	.05	.09	1.25		99.10	65.70	5.10	33.40	Sewer-pipe.
531	89	2.05	54.28	22.27	8.45	.45	.18	.60		100.11	67.57	11.01	32.51	Sewer-pipe.
532	90	2.20	70.75	13.87	5.01	.82	.29	1.15		99.09	39.40	7.27	59.70	Sewer-pipe.
533	85	1.17	70.15	15.51	3.34	.83	.07	3.75		99.96	39.46	7.09	60.50	Sewer-pipe.
534	85	1.43	71.00	15.27	3.33	.17	.21	2.12		99.53	42.83	5.83	56.70	Fire-brick.
<b>HALIFAX COUNTY.</b>														
535	117	1.63	67.55	13.16	8.54	.17	.28	2.65		99.06	41.98	11.64	57.08	Brick.
536	117	2.45	65.38	17.04	8.76	.72	.28	2.30		99.71	56.70	9.06	31.50	Brick.
537	118	2.05	59.68	16.09	8.91	1.35	.14	3.24		97.79	42.28	13.24	30.82	Brick.
<b>HARNETT COUNTY.</b>														
538	119	1.42	64.16	21.71	1.58	.23	.15	.77		99.40	53.55	3.81	40.90	Not worked.
539	120	1.35	50.68	32.51	3.06	.39	.02	.58		99.58	83.43	3.96	16.15	Not worked.
540	121	1.05	53.65	28.06	4.50	.10	1.35	.29		100.39	73.77	6.24	26.65	Not worked.
<b>JACKSON COUNTY.</b>														
541	61	.35	45.70	40.61	1.39	.45	.09	2.82		100.04	96.81	4.75	25.40	Whiteware.
542	62	.25	62.40	29.51	1.14	.57	.01	.98		100.66	66.14	1.70	31.52	Whiteware.
543	62	2.05	44.78	38.46	.28	.59	.04	.25		93.84	93.24	2.15	6.60	Whiteware.
544	59	3.07	44.08	38.26	1.86	.43	.29	13.56		99.96	91.21	2.99	5.75	Whiteware.
545	121	4.45	66.70	19.75	3.25	.45	.16	2.12		99.53	47.28	6.08	52.25	Not worked.

tearing in a stiff-mud auger machine, but not excessively plastic, otherwise laminations result.

From a commercial standpoint, it is of course desirable that the shrinkage in drying and burning should be moderate, and that the clay will permit drying in 24 to 36 hours. In fact, the lengthening of any of the stages of the process of manufacture increases the cost.

An important point is that the greater the difference in temperature between incipient fusion and viscosity the safer it is to thoroughly vitrify the brick. The difference in temperature between incipient fusion and viscosity should not be less than 250° F. and preferably 400° F.<sup>1</sup>

The color of a paving brick is no indication of its quality.

#### MANUFACTURE OF PAVING BRICK.

If shale is used it is first crushed in a dry pan and then screened.

The screened clay is mixed with water in a pugmill of the type described under building brick.

From the pugmill the clay passes into the stiff-mud machine, which has been already mentioned (p. 97). Few paving brick manufacturers now use anything except the auger machine. The brick may be either end-cut or side-cut according to the clay. Re-pressing the green brick is also commonly done, but the manner of re-pressing may have marked effect on the wearing power of the brick.

Experiments by Prof. E. Orton, Jr.,<sup>2</sup> have shown that end-cut re-pressed paving brick are the toughest.

The brick are generally piled on cars and run into tunnels to dry. These tunnels are heated by steam-pipes, or coal or oil fires.

The cars are run in at one end and always discharged from the other.

Paving brick should be burned in down-draft kilns, as they give far better results than the up-draft ones. The kiln may be either circular or rectangular. Circular kilns have small capacity and are cheap to erect, but little used outside of Ohio. Their capacity is about 25,000 brick.

Rectangular kilns of 150,000 to 200,000 capacity are the most used. There are several types, but their principle is the same. The flame and heat enter the kiln at the bottom and pass upwards in pockets set against the wall of the kiln and running half-way or three-quarters to the roof. The heat escapes from the top of the pockets or bags into the kiln, passes downward through the brick and out through the openings in the floor to the flues leading to the chimney.

<sup>1</sup> Olchewsky, in *Post. Chem. Tech. Analyse*, 1890, and Wheeler, *Vitrified Paving Brick*, 1895.

<sup>2</sup> *Clay Worker*, Feb. and March, 1897.





## CHEMICAL ANALYSES OF NORTH CAROLINA CLAYS.

Field No. used in this Report.	Chemical Laboratory No.	Page in Report where Described.	LOCALITY.	Moisture.	Silica (Total).	Alumina.	Ferric Oxide.	Lime.	Magnesia.	Alkalies.	Water Loss on Ignition.	Miscellaneous.	Total.	Clay substance.	Total Fluxes.	Free Sand.	Remarks.
No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12	No. 13	No. 14				
<b>BLADEN COUNTY.</b>																	
11	502	102	Upper brick-clay, middle of bluff, Prospect Hall .....	4.50	56.13	17.80	5.85	.10	.79	2.45	11.60*	Sulphur.	99.22		7.29	27.18	Not worked.
10	502	103	Middle brick-clay; bluff at Prospect Hall .....	2.80	63.30	15.87	5.48	.27	.21	2.40	8.25*	Sulphur.	100.36	43.06	10.14	57.30	Not worked.
12	559	103	Bottom brick-clay, bluff at Prospect Hall .....	4.26	55.65	20.86	5.11	.30	.64	2.13	9.94*	Sulphur.	100.07	85.03	9.36	15.05	Not worked.
<b>HUNCOMBE COUNTY.</b>																	
59	506	104	Upper clay, Penniman's, Emma .....	1.15	66.27	19.95	3.16	.20	.22	1.85	6.17	Ferrous oxide.	99.74	49.34	6.20	50.40	Brick.
58	578	105	Lower clay, Penniman's, Emma .....	.80	70.66	17.21	3.44	.10	.07	2.45	5.00		99.73	41.71	7.16		
65	572	107	Clay, Fletcher .....	1.10	75.08	13.73	3.47	.30	.17	1.48	4.65		99.98	45.18	5.42		
<b>BURKE COUNTY.</b>																	
51	512	75	Pottery clay, McDowell's, Morganton .....	1.68	60.58	14.03	6.41	.40	.27	1.65	5.73		99.75	45.47	8.73	54.28	Not worked.
52	514	107	Brick-clay, McDowell's, Morganton .....	1.80	67.03	16.88	6.50	1.00	1.16	.90	4.78		100.05	39.90	9.56	60.05	
<b>CATAWBA COUNTY.</b>																	
50	557	76	Pottery clay, northwest of Blackburn ..	2.08	50.17	28.77	2.88	.05	.22	1.04	14.03*		99.24	73.19	4.19	28.05	Stoneware.
<b>CLEVELAND COUNTY.</b>																	
43	516	81	Eskridge pit, Grover ..	.76	68.28	18.83	2.60	.70	.13	2.29	6.47	Titanic acid.	100.33	46.99	5.72	53.30	Fire-clay.
44	547	82	Powhatan Clay Manufacturing Co's pit, Grover .....	1.29	53.07	29.54	1.27	.15	.14	.87	9.93	Ferrous oxide.	98.54	61.99	4.71	36.55	White pressed brick.
45	571	83	Powhatan Clay Manufacturing Co's pit, 1/2 mile E. of Grover ..	.95	64.13	23.35	1.95	.10	.22	.99	1.81		98.48	46.88	5.07	51.60	
46	544	108	Under clay, Cleveland Brick Co., S. of Grover .....	1.18	61.75	23.30	3.34	.27	.25	1.31	7.75	Ferrous oxide.	99.65	60.62	5.67	39.05	Red brick.
47	522	109	Upper clay, Cleveland Brick Co., S. of Grover .....	.63	65.45	20.02	4.18	.25	.29	1.51	6.58		98.91	47.06	6.23	51.45	Red brick.
<b>CUMBERLAND COUNTY.</b>																	
14	569	110	E. A. Poe's pit, 1/2 mile S. of Fayetteville; average clay .....	2.10	64.00	17.08	5.57	.43	.59	3.85	6.58		101.51	53.13	10.44	45.90	Bricks.
15	569	111	E. A. Poe's pit, 1/2 mile S. of Fayetteville; average clay .....	2.10	64.00	17.08	5.57	.43	.59	3.85	6.58		101.51	53.13	10.44	45.90	Bricks.

[illegible]

## CLAY DEPOSITS IN NORTH CAROLINA.

In this Report.	Chemical Laboratory No.	Page in Report where Described.	LOCALITY.	Molature.	Silica (Total).	Alumina.	Ferric Oxide.	Lime.	Magnesia.	Alkalies.	Water Loss on Ignition.	Miscellaneous.	Total.	Clay substance.	Total Fluxes.	Free Sand.	Remarks.
				No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12	No. 13	No. 14
61	543	77	LINGOLN COUNTY. Pottery clay, T. Rhodes' place, 2 miles N. W. of Lincolnton.	2.10	57.20	24.82	3.25	.73	.13	.93	8.25	Ferrous oxide. 1.42	98.83	62.27	6.46	38.57	Stoneware.
49	534	78	Pottery clay, T. Rhodes' place, 2 1/2 miles N. W. of Lincolnton.	.60	57.08	26.11	4.64	.20	.16	1.42	8.52		98.82	62.76	6.42	35.96	Stoneware.
69	577	63	MACON COUNTY Crude kaolin, near West's mill; Brindley's land.		53.10	33.06	1.18	.38	.08	.83	11.32		99.95	83.39	2.47	16.56	
39	553	123	MECKLENBURG COUNTY D. K. Cecil's yard, Charlotte.	1.35	68.35	12.13	6.87	2.10	.32	2.82	5.20		100.18	38.73	12.15	61.45	Brick.
42	574	124	F. W. Shuman's yard, Charlotte.	7.10	59.15	18.86	6.04	.20	.34	1.72	7.47		100.38	39.50	8.30	59.50	Brick.
41	551	124	F. M. Sassamon's yard, Charlotte.	1.27	65.95	14.67	7.61	2.57	.25	2.55	5.52		100.36	43.84	12.98	56.45	Brick.
62	538	125	Upper clay, J. Asbury's yard, Charlotte.	.63	60.33	18.57	10.03	.20	.14	.55	7.83		98.23	56.23	10.92	42.05	Brick.
64	579	65	MONTGOMERY COUNTY. Dark kaolin, washed, 4 miles W. of Troy.	.52	86.03	6.46	2.14	.17	.04	1.00	2.90		99.27	20.83	2.35	78.54	
65a	576	66	White "	.75	63.10	23.33	2.97	.15	.09	1.90	7.65		99.94	53.92	5.11	41.06	
48	547	127	ROWAN COUNTY. D. K. Cecil's pit, Salisbury.	1.91	60.80	15.31	4.39	.55	.16	.70	6.37		99.28	47.38	5.80	51.90	Brick.
536	536	67	RICHMOND COUNTY. Kaolin, near Boatswain's mills.	.06	70.63	21.81	1.49	.20	.29	1.45	4.01		99.99	47.14	3.43	52.96	Not worked.
20	567	67	" " "	.17	68.15	19.99	1.96	.13	.16	2.85	4.70		98.01	49.30	5.00	50.70	Not worked.
23	568	67	" " "	"	73.70	16.03	1.57	.38	.47	1.90	4.83		98.98	36.06	4.32	61.33	Not worked.
23	564	126	R. L. Steele's pit, 4 miles N. of Rockingham.	1.98	59.59	22.07	4.27	.65	.49	2.70	7.53		99.28	51.63	8.11	47.65	Brick.
19	552	126	ROBESON COUNTY. Clay, Red Springs.	1.09	76.16	8.26	4.09	.40	.22	2.91	4.14		99.27	15.23	7.62	74.05	Brick
128	128	128	Pomona County. SUNNY COUNTY.										99.66	49.21	13.53	50.35	Not worked.





WAKE COUNTY.																	
23	130	Brick-clay, penitentiary pits, Raleigh..	25	Good.	9.3	4	13.3	123	144	Med. Fast.	Medium.	2000	2150	2300	5.72	Red.	2.54
WAYNE COUNTY.																	
7	132	Brick-clay, H. L. Grant's pit, Goldsboro	33	Fair.	8	6	14.00	63	74	Med. Fast.	Coarse to Fine.	1940	2100	2300	7.76	Red.	2.53
8	134	Clay, Weil's pits, Goldsboro.....	25	Good.	8.3	3	11.3	85	102	Slowly.	Fine.	1940	2100	2300	5.86	Light red.	2.57
9	133	Fire-clay, H. L. Grant's pit, Goldsboro.	25	Good.	8.5	5	13.5	107	125	Mod. Fast.	Fine.	1850	2150	2300	8.17	Deep red.	2.55
WILKES COUNTY.																	
31	78	Pottery clay, just west of Wilkesboro.	40	Moderate.	7.5	12	19.5	51	63	Slow.	Fine.	1900	2050	2200	7.02	Red.	2.37
33	79	Pottery clay, Calvin Cowles' property.	35	Good.	10	5	15	169	192	"	Fine.	1900	2000	2200	8.62	Gray-brown.	2.46
36	134	8 miles north of Wilkesboro.....	25	Lean.	5	10	15	74	76	Fast.	Fine.	1940	2100	2300	12.75	Deep red.	2.63
37	135	Brick-clay, D. Smook, Wilkesboro.....	24	Lean.	6	9	15	71	84	"	Med. Fine	1900	2160	2300	17.44	"	2.44
WILSON COUNTY.																	
4	136	Red top clay, Lucas' S. pit, N. E. of Wil-	32	Lean.	10	5	15	84	98	Fast.	Medium.	1900	1950	2100	14.31	Red.	2.62
5	137	Blue top clay, Lucas' N. pit, N. E. of	30	Good.	8	5.5	13.5	107	129	Slow.	Medium.	1900	2050	2200	8.08	Red.	2.45
6	138	Blue top clay, Lucas' bank, East of Wil-	33	Good.	11	4	15	138	155	Slow.	Medium.	1950	2100	2250	7.60	Red.	2.52

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